Applications of Nickel Matrix Composite Coatings in Textile Industry Equipment

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Several spare parts of the equipment in textile industry should exhibit some special characteristics due to their continue contact with very sensible materials, such as yarns, filaments, clothes. These parts must be very smooth, hard and possess very good wear resistance.

In practice, manufacturers use very often hard chromium coated parts, which become useless in short periods of time due to their heavy duty performance and, consequently, must be substituted frequently.

In this work, we have tried to substitute the hard chromium coatings by nickel matrix composite coatings, in order to ameliorate the surface aspect and the tribological properties. We have used nickel matrix coatings containing silicon carbide (SiC) micro-particles, prepared under pulse plating conditions.

It has been proved that this technique, under very well defined conditions (pulsed current density, frequency, duty cycle, etc), permits us to obtain hard and smooth coatings, even in the absence of organic additives, which show improved tribological properties. As a result of this work, we have substituted certain chromium coated equipment components of the textile industry by these composite coated ones.

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Introduction

Operational problems due to wear appearing on various components is a fact that almost every industrial installation has to deal with. One of the most important goals of the maintenance departments of the industrial plants is to find solutions for the better preservation from wear of their equipment, so as to increase their lifetime performance.

The severity of this problem can be illustrated by the fact that almost the 30% of the energy produced in the industrial zones worldwide is consumed in erosion– wear– corrosion phenomena.

As far as textile industry is concerned, operational problems usually appear due to mechanical erosion, abrasive wear, adhesive wear, fatigue and chemical corrosion. The stages that introduce the most important operational problems that reflect to the quality of the textile are the ginning and the spinning. For the operating components of these stages, the requirements are: smooth surfaces, surfaces with reduced porosity and increased hardness and wear resistance.

It is evident that there is an increasing need for development of new materials with improved and well controlled properties, enabling industrial components to perform better erosion–wear–corrosion resistance during operation. And it seems that a satisfying solution is the coverage of the components' surface (mainly metallic) with deposits having the desired properties.

Metal matrix composite materials (MMCs) are probably promising materials for the substitution of the problematic components in textile industry, because of the superior mechanical properties they exhibit. The surface deposition of these components with MMCs can ameliorate their performance and prolong their substitution with new ones. Moreover, by appropriate selection of matrix materials, reinforcements, and layer orientations, it is possible to tailor the properties of a component to meet the needs of a specific design.

Numerous combinations of matrices and reinforcements have been tried. However, MMC reinforcements generally are ceramics. At this time, the leading discontinuous fiber reinforcements are alumina and alumina-silica, while the major whisker material is silicon carbide.

Compared to simple metallic materials, MMCs have:

- Higher strength-to-density ratios
- Higher stiffness-to-density ratios
- Better fatigue resistance
- Better wear resistance
- Better mechanical behavior at elevated temperatures(higher strength, lower creep rate)
- Lower coefficients of thermal expansion

Nickel composite electrodeposition

Nickel as a deposition metal can be found at many applications and its wide use is due to its special characteristics. Nickel is easily deposited, has a well corrosion resistance, increased hardness and gives many different types of deposition by simple alterations of the electrolytic conditions[1,2].

Industrial applications for the improvement of the macroscopic properties of the nickel deposits used to be focused on the use of various additives (brighteners, levellers, and wetting agents). Nowadays, though, their use is reduced because of their high cost and the strict environmental legislation. Their replacement by pulse current plating techniques can lead to the production of smooth nickel surfaces with improved properties, while the codeposition of silicon carbide particles in the nickel matrix can ameliorate even more the triboligical properties of the nickel substrate[2-4]. This amelioration depends mainly on the size and the percentage of the silicon carbide particles codeposition, as well as on the distribution of these particles in the nickel matrix.

Pulse current composite electrodeposition

The factors that influence the structure and the properties of the composite electrodeposites are the following[4-8]:

- composition of the electrolytic bath
- temperature of the electrolytic bath
- pH of the electrolytic bath
- aggitation of the electrolytic bath
- type and size of the particles
- concentration of the particles
- aggitation of the particles
- type of the current regime (continuous or pulse)
- current density
- time duration of the electrodeposition

In the case that there is a pulse current regime, two more factors have to be added:

- the frequency of the imposed pulses
- the duty cycle of the imposed pulses, that is the ratio $T_{on}/(T_{on}+T_{off})$, where T_{on} is the time period the pulses are imposed

Experimental results

The first step was the selection of the codeposition parameters, which concluded from the experience in pulse electrodeposition, while the second step was to carry out experiments in order to test the selected parameters. Therefore, experimental tests were performed on the system Watts-Ni/SiC (SiC of a mean diameter 20 • m) on a rotating disc electrode (RDE) under pulse plating conditions. The substrates were brass cylinders and stainless steel components (Figures 1-3) that were chemically and mechanically cleaned and polished. The experimental parameters for the sample preparation are given in • able 1.

Figure 1 – Ring type component

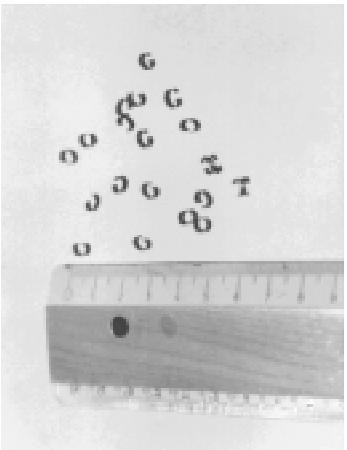


Figure 2 – Clasp type component

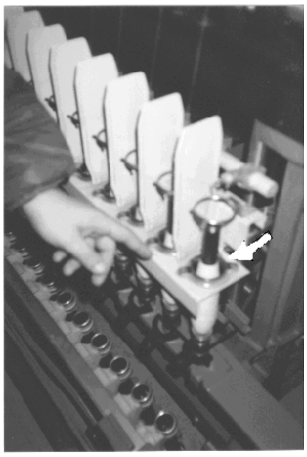


Figure 3 – White arrow shows where the system of ring and clasp type components are applied on a textile machine

Table 1
Experimental parameters for the preparation of Ni/SiC composite electrodeposits

electrolyte Watts bath	300 g/l $NiSO_4{\cdot}7H_2O$, 35 g/l $NiCl_2{\cdot}6H_2O$, 40 g/l H_3BO_3 pH = 4.40 • = 50 ^{0}C
SiC powder (20 • m mean diameter)	20 g/l (in suspension with magnetic stirring)
substrate	brass cylinders (diameter 25 mm - 1 inch) stainless steel components
Cathode's rotation velocity (•)	200 rpm
current density (J_p)	5 A/dm^2 - value that gives a perfect texture [211] under DC conditions
duty cycle (•)	5 %, 10 %, 30 %, 50 %, 70 %, 90 %
pulse frequency (•)	0.01, 0.1, 1, 10, 100 Hz

It is well known that SiC codeposition in a metallic matrix alters the mechanical properties of the deposit[4,9]. Therefore, Vickers microhardness (HV) measurements and roughness measurements were performed.

Moreover, the morphology of the composite electrodeposits was studied by the use of Scanning Electron Microscopy (SEM) and X-Ray Diffraction techniques (XRD). The percentage of SiC codeposition was measured by the use of Energy Dispersive Spectroscopy (EDS).

Surface morphology

SEM, EDS and XRD techniques revealed the influence of pulse current regime on the mechanism of SiC codeposition.

The analysis of the deposits by SEM and XRD techniques showed that SiC powder is well codeposited in the metal matrix, even during the initial stages of the nickel crystallization, and that the SiC particles are well incorporated in the Ni matrix. Additionally, it seems that the codeposition mechanism is better favored by the submicron particles (than micron-sized ones), because they are not only codeposited at the borders and the edges of the nickel crystallites, but they are also incorporated in the nickel crystals (Figures 4,5). Ultrasonic cleaning of the composite surfaces proved that SiC is well codeposited and not absorbed on the Ni matrix.

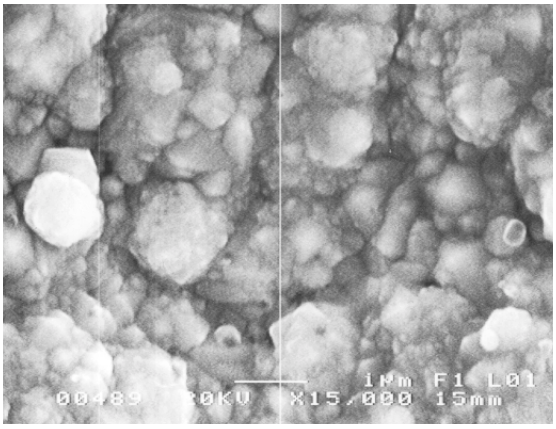


Figure 4 – Morphology of composite Ni/SiC deposit, duty cycle = 90% and v = 0.1 Hz

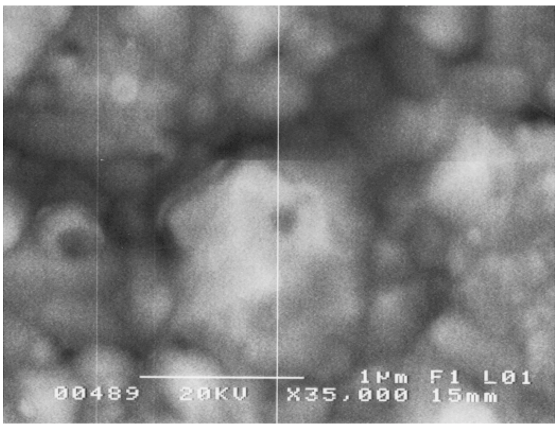
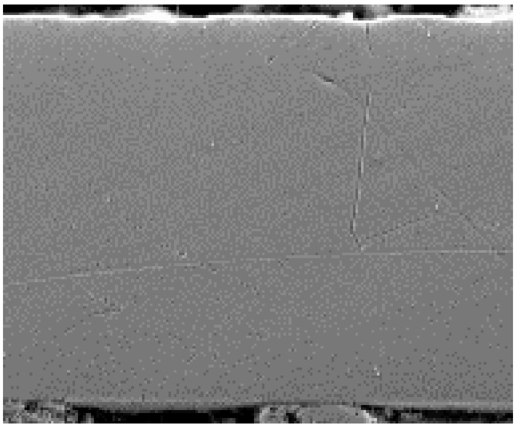


Figure 5 – a detail of the above surface area where SiC particles can be seen incorporated in the Ni crystallites

The study of deposits' cross-sections by SEM and EDS techniques lead to the conclusion that pulse current regime gives composite deposits with uniform particles distribution (Figures 6,7).



magnification x 500 ---- 10 • m

Figure 6 - Cross-section of composite Ni/SiC deposit, duty c.ycle= 90% and v = 0.1 Hz

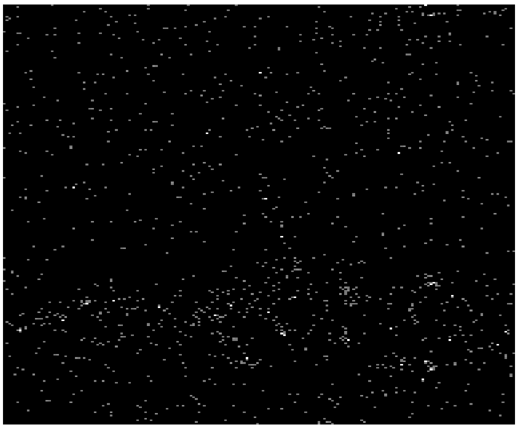


Figure 7 - Si mapping of the above cross-section of composite Ni/SiC deposit

The embedding of the SiC particles in the nickel matrix influences significantly the surface morphology of the deposit, as the size of the nickel crystallites is decreased. Moreover, an important factor of this alteration is the size of the particles, as nano-sized SiC leads to the production of more microcrystalline surface structures[10] (Figure 8).

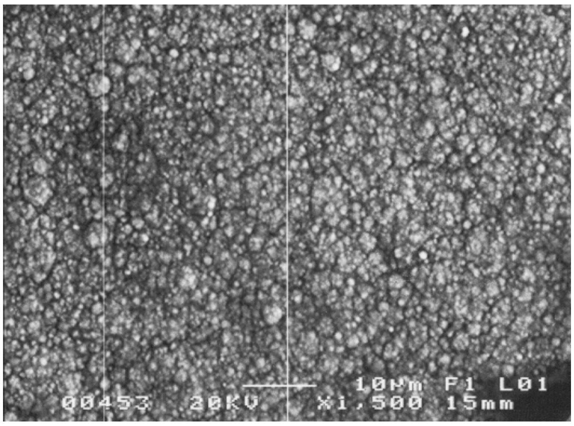


Figure 8 – Morphology of composite Ni/SiC deposit, duty cycle = 10% and v = 0.1 Hz

Roughness

Roughness measurements of the composite electrodeposits prepared under pulse current regime confirmed the expectation that composite electrodeposits have lower roughness values, as indicated in • able 2, than the corresponding values of pure nickel electrodeposits prepared under the same conditions. This could be associated to their observed microcrystalline surface structure.

Table 2
Roughness values of Ni/SiC composite electrodeposits

duty cycle	Ra (• m)	Rt (• m)	Rz (• m)
90%	0.14 – 0.40	1.7 – 4.4	1.1 – 3.6
50%	0.10 – 0.37	1.1 – 3.9	0.7 – 2.5
10%	0.13 – 0.34	1.7 – 3.1	1.0 – 2.2

It is noticed that for every duty cycle, samples for every selected frequency were measured, that is for: 00.1 Hz, 0.1 Hz, 1 Hz, 10 Hz and 100 Hz. Additionally, pure nickel coatings prepared under the same conditions give roughness values (Ra) between 0.30 – 0.80 • m.

Microhardness

Experimental measurements showed that Ni/SiC composite deposits prepared under pulse and direct current regime have higher Vickers microhardness values (HV in • p/mm^2) than pure nickel deposits prepared under pulse and direct current regime[10].

The hardness values of Ni/SiC composite deposits prepared under pulse current regime vary between 350 – 820 • p/mm^2, while the hardness values of pure nickel deposits prepared under pulse current regime vary between 220 - 350 • p/mm^2 and the hardness of Ni/SiC composite deposits prepared under direct current regime vary between 300 – 350 • p/mm^2.

Conclusions

Concluding, it is obvious that SiC codeposition in combination with pulse current regime lead to the production of composite surfaces with better performance characteristics: the surface roughness is significantly decreased, while the surface microhardness is remarkably increased. These properties are among the most crucial parameters for the heavy performance of the textile industrial components and, consequently, deposition of some of these components with Ni/SiC coatings can lead to highly promising technological applications.

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