Study of Interaction Effects Between Two Electrochemical Bath Parameters on Properties of NI-SIC Nanocomposite Coatings

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ABSTRACT:

Ni-SiC nano-composite coatings were prepared on a Mild steel substrate by electro-co-deposition process using a sulphamate bath. SiC loading, Current density and bath temperature were varied and the electrochemical bath parameters were measured. In the present work, the effect of electrochemical bath parameters such as bath temperature, bath loading and current density on physical and mechanical properties of Nickel based SiC composite coating on Mild Steel substrate was studied using Taguchi technique.
Interactions between two parameters for different outputs were plotted using a statistical software. The Experimental results showed that Microhardness and tensile strength were maximum for SiC loading at 4 gm/l and at a bath temperature of 55^{o}C and coating thickness was maximum for SiC loading at 6 gm/l and 65^{o}C bath temperature.

Keywords: Electro-co-deposition, SiC nanoparticles, Microhardness, Microstructure, Tensile Strength, Coating Thickness, Taguchi.

INTRODUCTION:

The Taguchi technique is a powerful tool for design of high quality systems based on orthogonal array experiments that provide much reduced variance for the experiments with an optimum setting of process control parameters. This method achieves the integration of design of experiments (DOE) with the parametric optimization of the process yielding the desired results. The orthogonal array (OA) requires a set of well balanced (minimum experimental runs) experiments. In this method, main parameters, which are assumed to have an influence on process results, are located at different rows in a designed orthogonal array. With such an array, completely randomized experiments can be conducted.

Incorporation of various particles with nickel has been commonly reported in the literature [1, 2]. Among them oxides (e.g.: Al_2O_3, ZrO_2, TiO_2) or carbides (e.g.: SiC, WC, TiC) as hard ceramic particles were used for improvement of hardness or wear resistance as well as thermal stability of the coatings. Electrodeposited nickel matrix composites with SiC particles seem to be the most often studied systems [1, 2, 4-7]. It is mainly due to feasibility of particle incorporation in a low-cost process. Nickel based electrochemical composite coatings have good corrosion properties and enhanced electrochemical activity for hydrogen and oxygen evolution compared to the base metal. These coatings are also used for the protection of machine parts subjected to aggressive environments. The development of modern technology requires metallic materials with better surface properties. Coatings that consist only of nickel may not meet these requirements. As a result composite materials with new structures and special properties have become the focus of attention for the researchers. Ni based coatings are not only used for decorative purposes but also as functional coatings for resistance to corrosion, wear and refractory applications. The adsorption of cations on the ceramic particles not only affects the surface charge but also determines the codeposition process. It is commonly accepted that a positive surface charge can enhance codeposition, because the particles are electrostatically attracted to the cathode. Moreover, the reduction of metal ions adsorbed on the particles is required for irreversible incorporation of the particles [1, 2, 5, 9]. The aim of this investigation was to determine the influence and current density and concentration of the particles in the plating bath on the composition and morphology of the Ni/SiC composites.

EXPERIMENTAL STUDY

The specimens were prepared and experiment has been conducted as per ASTM standards.The specimens once cut were buffed, cleaned up with soap, water and ultrasonically degreased with acetone and then rinsed with 5% sulphuric acid solution at room temperature for 3 minutes. Finally, it was rinsed in deionized water for 5 minutes. In this experiment, over 27 samples (3 samples size for each condition) were coated under different bath conditions such as SiC loading, current density and bath temperature for conducting the tensile test.

Table 1 shows the Orthogonal design array selected for the experimentation. The arrays for the 27 experiments were selected from the orthogonal array $\mathbf{L_{27}\ (3^{13})}$.

Table 1. Orthogonal design array selected for experimentation

Expt. No.	Experimental condition		
	SIC Loading gm/l	Current Density A/dm^2	Bath Temp. ^{0}C
01	2	2	45
02	2	2	55
03	2	2	65
04	2	3	45
05	2	3	55
06	2	3	65
07	2	4	45
08	2	4	55
09	2	4	65
10	4	2	45
11	4	2	55
12	4	2	65
13	4	3	45
14	4	3	55
15	4	3	65
16	4	4	45
17	4	4	55
18	4	4	65
19	6	2	45
20	6	2	55
21	6	2	65
22	6	3	45
23	6	3	55
24	6	3	65
25	6	4	45
26	6	4	55
27	6	4	65

Table 2 shows the assignment of levels to the factors which are considered for this work. It has three levels for three different parameters like SiC loading, Current density and Bath temperature.

Table 2. Assignment of the levels to the factors

Factor	Name	Units	Level 1	Level 2	Level 3
A	SIC Loading	gm/l	2 (A1)	4 (A2)	6 (A3)
B	Current density	A/dm^2	2 (B1)	3 (B2)	4 (B3)
C	Bath Temperature	^{0}C	45 (C1)	55 (C2)	65 (C3)

Table 3. Results obtained after experimentation

Expt. No.	Responses		
	Thickness µm	MicrohardnessHv	Tensile strength Mpa
1	08.5	0548.46	670
2	12.3	0708.32	708
3	18.7	0656.42	695
4	12.2	0618.38	688
5	20.2	0718.00	714
6	28.5	0671.90	700
7	15.2	0536.30	667
8	25.4	0672.16	702
9	38.1	0639.12	690
10	12.8	0670.35	700
11	24.2	1014.48	780
12	45.1	0925.01	755
13	18.7	0804.68	735
14	42.0	1244.42	840
15	58.2	0948.29	760
16	23.5	0774.00	728
17	52.3	1115.03	820
18	76.5	0924.63	755
19	16.8	0671.87	700
20	29.5	0886.00	750
21	54.2	0802.00	730
22	31.7	0745.16	715
23	56.2	0998.00	762
24	65.2	0786.89	710
25	36.2	0665.00	685
26	58.1	0826.00	738
27	78.8	0819.83	728

RESULTS AND DISCUSSION

The following are the results obtained after conducting the experimental work for 27 specimens at different loading conditions.

Fig 1 shows the interaction effects of bath parameters on microhardness of Ni-SiC composite coatings on a MS substrate. It can be seen from the graph that the interaction between SiC loading with a value of 4 gm/l and bath temperature with a value of 55^{o}C have maximum effect on microhardness.

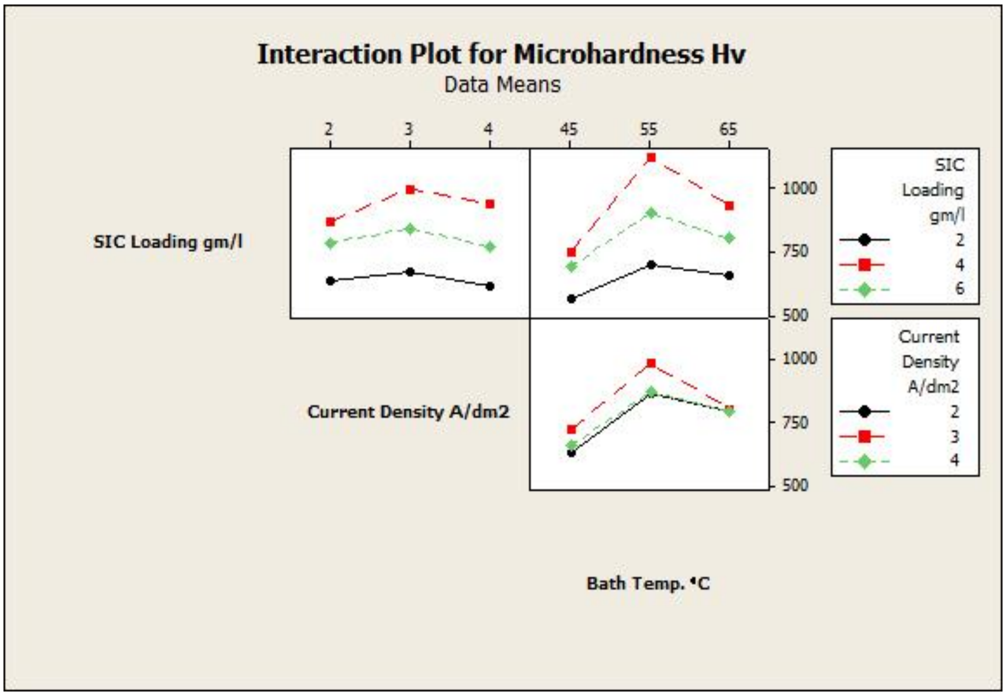

Fig 1 – Interaction effects plot for Microhardness

Fig 2 shows the interaction effects of bath parameters on Tensile strength of Ni-SiC composite coatings on a MS substrate. It can be seen from the graph that the interaction between SiC loading with a value of 4 gm/l and bath temperature with a value of 55°C have maximum effect on Tensile strength.

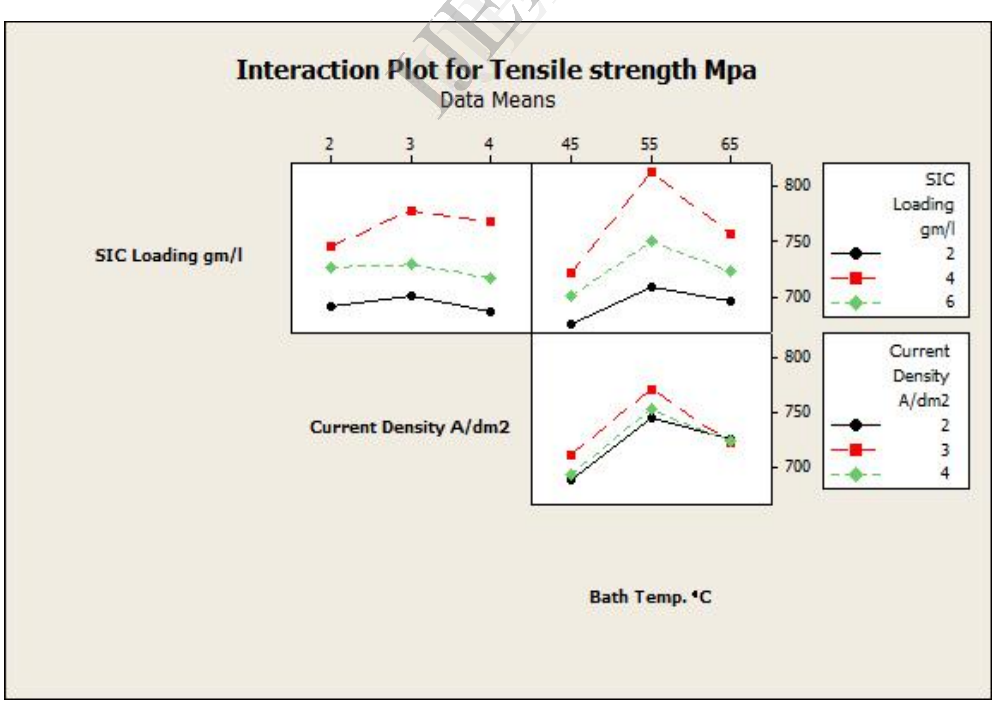

Fig 2 – Interaction effects plot for Tensile strength

Fig 3 shows the interaction effects of bath parameters on coating thickness of Ni-SiC composite coatings on a MS substrate. It can be seen from the graph that the interaction between SiC loading with a value of 6 gm/l and bath temperature with a value of 65°C have maximum effect on microhardness.

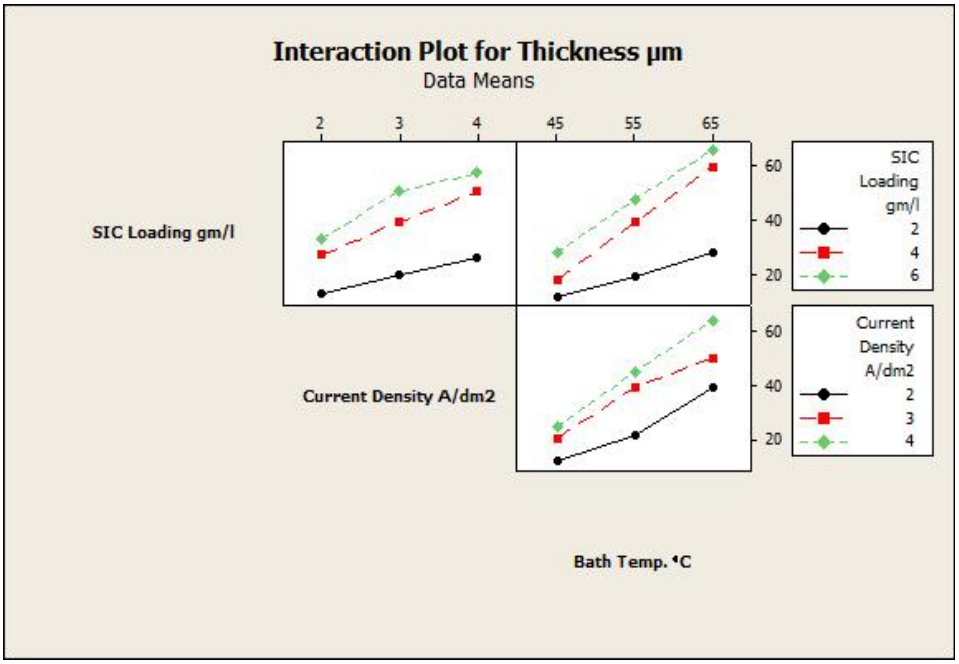

Fig 3 – Interaction effects plot for Thickness

CONCLUSION

- 27 experiments were conducted by selecting Orthogonal arrays to obtain maximum possible combinations.
- Graphs were plotted by taking two factors at one time and keeping the third parameter as constant.
- It was observed that the interaction between SiC loading at 2gm/l and a bath temperature of 45^{o}C has the least effect on the electrochemical parameters studied in this research.
- Whereas the interaction between SiC loading of 4 gm/l and bath temperature of 55^{o}C has maximum effect on electrochemical parameters like microhardness and tensile strength.
- Also SiC loading at 6 gm/l and bath temperature of 65^{o}C has the most effect on the thickness of the coating.

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