

INTERNAL STRESS OF ELECTRODEPOSITS OF NICKEL ON HIGH STRENGTH HIGH CARBON STEEL

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Bath composition and operating conditions have been standardised for producing low stressed nickel deposits on high strength, high carbon steel. Deposits produced under the optimised conditions have stress values 5-6 times lower than that of those produced from a conventional Watt's electrolyte.

Key words: Internal stress, high carbon steel, electrodeposition of nickel

INTRODUCTION

The increasing demand for newer materials with increased strength and toughness especially in aeronautics has opened up new possibilities in the utilisation of high strength steels [1]. Such materials though useful from the view point of material performance, need proper protection against corrosion by means of a suitable electroplating process. But the deposits so produced assume certain undesirable properties like high internal stress and cohesion, if a proper sequence of electrofinishing is not followed. Special pretreatments and plating conditions should be considered that can avoid such difficulties and also can minimise hydrogen intake by substrate materials.

Sulphamate baths are normally recommended for producing ductile nickel deposits with low internal stress [2]. However, no data is available on the stress produced when high carbon steel is plated. The aim of this paper is to compare the internal stress of nickel deposits produced from Watt's and sulphamate electrolytes on substrates of a special high carbon steel containing C:1.1%, Si: 0.05%, MnO: 0.7%, and P and S 0.5% each, and with $165 \text{ kg} \cdot \text{mm}^{-1}$ tensile strength.

EXPERIMENTAL

Watt's and sulphamate nickel formulations of varying compositions were taken for production of deposits for stress measurements under different operating parameters such as pH, current density and temperature. The electrolytes used are of the composition given below unless otherwise specified.

Watt's electrolyte ($\text{g} \cdot \text{l}^{-1}$)	Sulphamate electrolyte ($\text{g} \cdot \text{l}^{-1}$)
Nickel sulphate: 250	Nickel sulphamate: 290
Nickel chloride: 30	Nickel chloride: 10
Boric acid: 40	Boric acid: 30

Operating conditions

pH	4.0	4.0
Temperature	331K	328K
Current density	$3 \text{ A} \cdot \text{dm}^{-2}$	$2 \text{ A} \cdot \text{dm}^{-2}$

High carbon (Spring) steel specimens of $16.0 \times 1.0 \times 0.015 \text{ cm}^3$ size with an effective plating area of $8 \times 1 \text{ cm}^2$ were used as

substrates. The specimens were anodically cleaned in an alkaline cleaner of the conventional type for 2 minutes before plating.

Stress measurements were carried out by filament deflection method of Hoar and Arrowsmith as described elsewhere [3].

RESULTS AND DISCUSSION

In general, the stress values obtained in the case of plated high carbon steel are higher than the values obtained for cold rolled steel. This behaviour can be anticipated on the basis of the high carbon content, higher tensile strength and tempered nature of the specimens used. Stress values for nickel deposition from a sulphamate bath were found to increase with reduction in metal ion concentration (Fig. 1) of the bath or when chloride content (Fig. 2) was raised [4]. It was therefore, necessary to optimize the parameters for depositing low stress nickel deposits on high carbon steel.

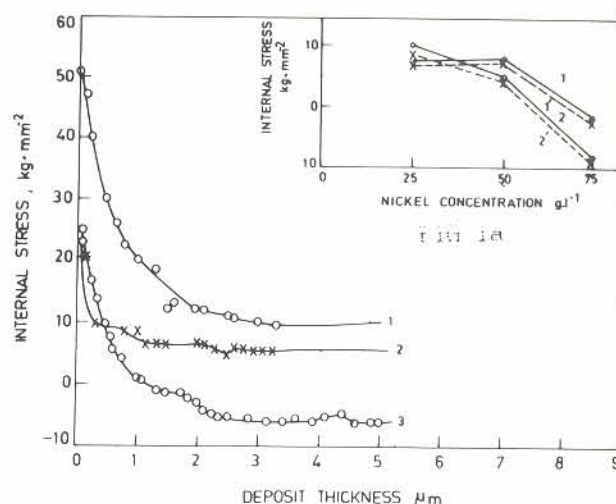


Fig 1 : Influence of nickel concentration in sulphamate bath on deposit stress, pH = 4; $T = 328 \text{ K}$; current density = $2 \text{ A} \cdot \text{dm}^{-2}$. Bath contains $5 \text{ g} \cdot \text{l}^{-1}$ of $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$. Ni concentration ($\text{g} \cdot \text{l}^{-1}$): (1) 25 (2) 50 (3) 75
Fig 1a: Effect of current density and thickness (1) $3 \text{ A} \cdot \text{dm}^{-2}$, $3 \mu\text{m}$. (2) $2 \text{ A} \cdot \text{dm}^{-2}$, $3 \mu\text{m}$ (1') $3 \text{ A} \cdot \text{dm}^{-2}$, $2 \mu\text{m}$ (2') $2 \text{ A} \cdot \text{dm}^{-2}$, $2 \mu\text{m}$.

Figures 1a and 2a (insets) give a clear picture of the variation of stress with nickel content and nickel chloride concentration

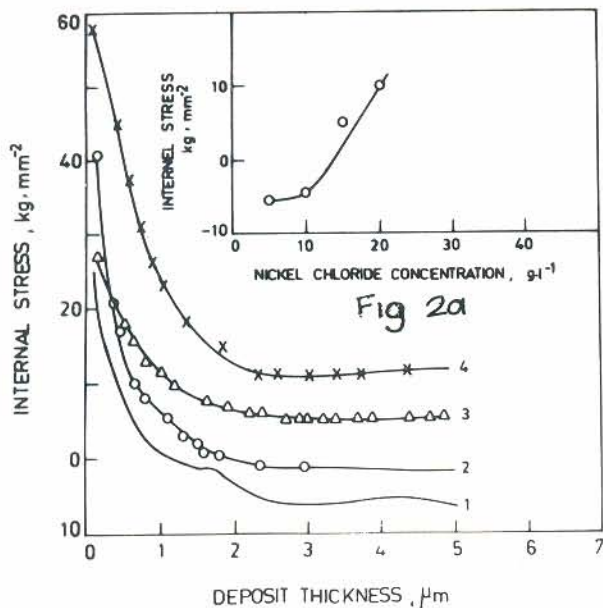


Fig 2: Effect of chloride ion concentration of sulphamate bath on internal stress of nickel deposits, current density: 2.0 A.dm⁻²; pH: 4.0, T: 328K; Nickel chloride concentration, g.l⁻¹ (1) 5.0 (2) 10.0 (3) 15.0 (4) 20.0

respectively. One can thus conclude that with an electrolyte containing 75 g.l⁻¹ of nickel and upto 12 g.l⁻¹ of nickel chloride, it is possible to obtain expansively stressed nickel deposits at a current density of 2.0 A.dm⁻²

Stress values for sulphamate nickel deposit increase with increasing current density of deposition (Fig. 3), increase in electrolyte pH (Fig. 4) and decreasing electrolyte temperature (Fig. 5).

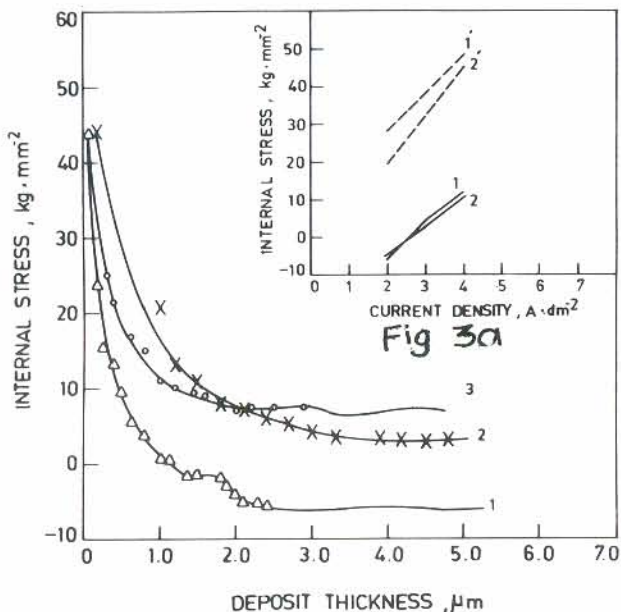


Fig 3: Effect of current density on internal stress of sulphamate nickel deposit (sulphamate with 5.0 g.l⁻¹ nickel chloride, pH 4.0, 328 K) Current density, A.dm⁻²: (1) 2.0 (2) 3.0 (3) 4.0. Fig 3a: thickness, (1) sulphamate bath, 3μm (1') Watt's bath, 3μm (2) sulphamate bath, 2μm (2') Watt's bath, 2μm

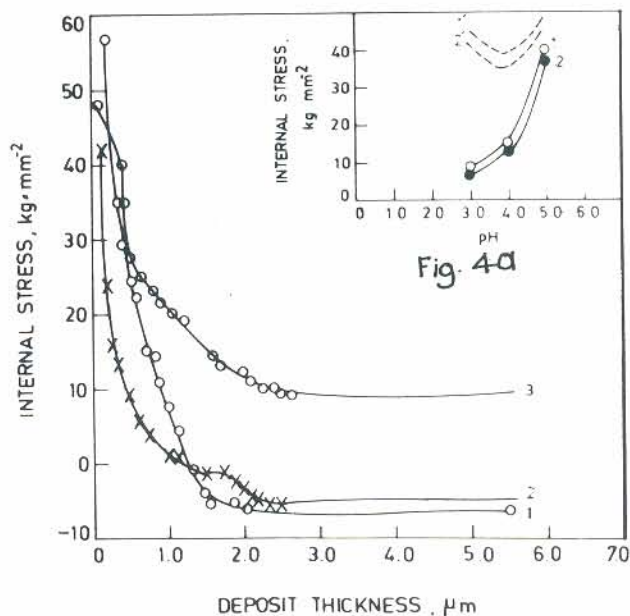


Fig 4: Effect of pH on internal stress of sulphamate nickel deposit. Sulphamate bath with 5g.l⁻¹ NiCl₂·6H₂O. current density, 2.0 A.dm⁻²; 328 K, pH: (1) 3.0 (2) 4.0 (3) 5.0

Fig 4a: Thickness: (1) sulphamate bath, 3μm (1') Watt's bath, 3μm (2) sulphamate bath, 4μm (2') Watt's bath, 4μm. The nickel sulphamate bath contains 20g.l⁻¹ of chloride. Current density: 3 A.dm⁻²

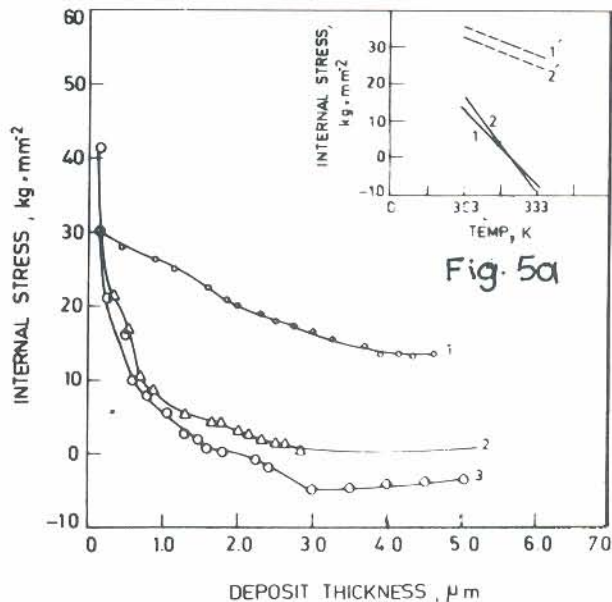


Fig 5: Effect of temperature on internal stress of sulphamate nickel deposit Bath containing 10 g.l⁻¹ NiCl₂·6H₂O at pH 4.0 Current density, 2.0 A.dm⁻². (1) 303K (2) 318K (3) 328K

Fig 5(a): Thickness: (1) sulphamate bath, 3μm (1') Watt's bath, 3μm (2) sulphamate bath, 4μm (2') Watt's bath, 4μm

Since all the above variations cause a higher surface pH at the interface between the cathode and the solution due to high rate of hydrogen evolution, it is probable that these conditions might have led to incorporation of hydrogen into the substrate metal and of basic nickel compound into the deposit, giving rise to a higher stress in deposit [5].

The results show that by operating the sulphamate electrolyte

at 2.0 A.dm^{-2} , 328 K and at a pH of 4.0, one can produce compressively stressed deposits even on a substrate prone to high internal stress. Figures 3a, 4a, and 5a compare the internal stress of deposits obtained from a sulphamate and Watt's type electrolytes. Under identical conditions of operation, stress values obtained for deposits from a Watt's solution are found to be 5–6 times higher than those obtained from a sulphamate electrolyte.

CONCLUSION

The extent of internal stress developed in nickel deposits from a Watt's nickel electrolyte may, depending on the operating parameters, be upto 5–6 times that in a sulphamate electrolyte. Compressively stressed nickel deposits can be obtained on high

carbon steel from a nickel sulphamate bath containing 75 g.l^{-1} nickel and 10 g.l^{-1} nickel chloride and at $I = 2.0 \text{ A.dm}^{-2}$; $T = 328\text{K}$ and $\text{pH} = 4.0$.

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