THE PROCESSING OF HARDNESS COATINGS NI-P/SIC HEAT TREATED AT 300^{0}C WITH A MATHEMATICAL MODEL

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Abstract: This paper present the experimentally results of Vickers microhardness values for electrochemical Ni-P/SiC coatings treated at 300 ^{0}C obtained by applying a series of small loads on the indenter have been processed according to a mathematical Hays – Kendall model in order to eliminate the troublesome ISE effect (load dependence of hardness) and obtain a unique value representing the true hardness for each coating.

1. INTRODUCTION

Indentation hardness is the simplest method to characterize the mechanical properties of materials. Its usefulness has been greatly enhanced by the modern possibility to apply hardness tests at microstructural and even at nanoscale level. Since the indentation hardness test is performed by applying a pressing force F on the polished surface of the specimen and by measuring the area of the impression left by a hard standardized indenter or its depth of penetration.

2. THE HAYS-KENDALL THEORETICAL MODEL FOR THE ISE EFFECT

This model attempts to conciliate the Kick law with the ISE effect.
The Kick law involves the supposition that microhardness is constant for a given substance.
The Kick law suppose a quadratic relationship between load F and size d of the indentation diagonal:

$$F = ad^2 \tag{1}$$

This type of relationship between the measurable quantities F and d is just a straight forward consequence of the definition of the indentation hardness that is obtained by dividing the load F to the area of the indentation H = F / A. Indeed for the Vickers diamond pyramidal indenter with an apex angle 136°, the microhardness HV is calculated as:

$$Hv = \frac{F}{d^2 \sin\frac{136^0}{2}} = 1854{,}4\frac{F}{d^2} = a'\frac{F}{d^2} \tag{2}$$

where HV is expressed in kgf/mm^2, F is expressed in gram.force and d is expressed in micrometers. If the load F is expressed in milliNewton the numerical constant a' in eq. (2) becomes 189,1 while the hardness HV is expressed in daN/mm^2.
Ecuation (2) may be rearranged:

$$F = \frac{HV}{a'}d^2 \tag{3}$$

It is obvious that if one supposes the hardness HV being constant for a given material a new constant:

$$K = \frac{1}{a'} HV \tag{4}$$

appears in eq.(3). So eq. (3) has transformed it self into eq. (2) that is just the Kick law.
Unfortunately the ISE effect invalidates the Kick law if the applied load is low. In fact at low values for the applied load F the indentation hardness appears to be dependent on F.
The problem that arises is how to conciliate the Kick law with the existence of the ISE effect, that in some experimental conditions invalidates it. A way to do this was proposed by Hays and Kendall [3] and it was mainly applied for metallic materials. In this theoretical model the Kick law is admitted to be valid in whatever conditions but the effective load F_{eff} involved in producing the plastic deformation responsible for the appearance of the indentation is less than the applied load F by a quantity W. Then the Kick law must be written as follows:

$$F - W = Kd^2 \tag{5}$$

where W represents the resistance of the material to yielding or the force required to initiate the plastic deformation in the material. Then eq. (5) may be rewritten as follows:

$$F = W + Kd^2 \tag{6}$$

3. EXPERIMENTAL RESULTS

A series of Vickers microhardness tests have been performed at various applied loads F from 15 to 500 gram force for a three material composites Ni-P/SiC. The size d of the indentation diagonal was taken as the average of ten measured values for each material composites Ni-P/SiC and each applied load F.
The Ni-P/SiC composites was obtained with variation of the electrolytic bath. A complex aqueous electrolyte was used containing $NiSO_4 \cdot 6H_2O$; $NiCl_2 \cdot 6H_2O$, content variable of H_3PO_3, and having its temperature maintained at 80 ^{0}C and pH kept constant at 2. The amount of the active component for the co-deposition of phosphorous in the Ni matrix namely H_3PO_3 was increased in steps in the electrolyte (5, 20 g/l H_3PO_3). A device was provided to keep in suspension the micronic SiC powder particles intended to be incorporated in the coating. The coatings have been symbolized P_xS_y where x is the amount of H_3PO_3 dissolved in the electrolyte (in g/litre) and y is the amount of SiC particles in suspension in the electrolyte (in g/litre).
Three Ni-P/SiC composite coatings have been selected for the hardness investigation wich have been denoted P0S40, P5S40 and P20S40.
In the series of figures Fig. 1-3 we have represented the dependence $F=f(d^2)$ for three material composites Ni-P/SiC by treatment to 300^{0}C taken under study.

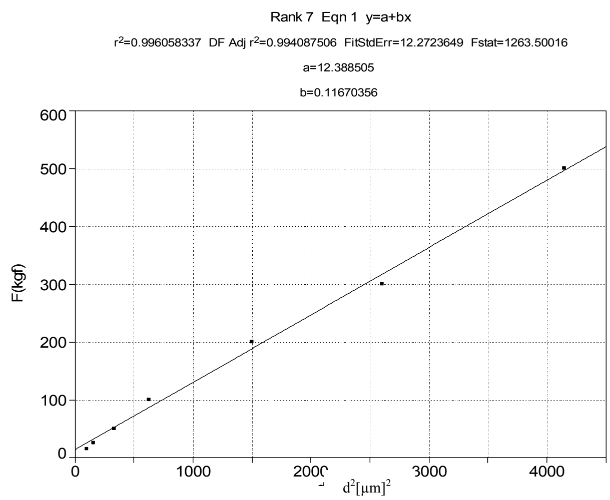

Fig.1: Quadratic plot for P0S40 $_{tt300}{}^0C$ ***(Hays-Kendall model F=W+Kd²)***

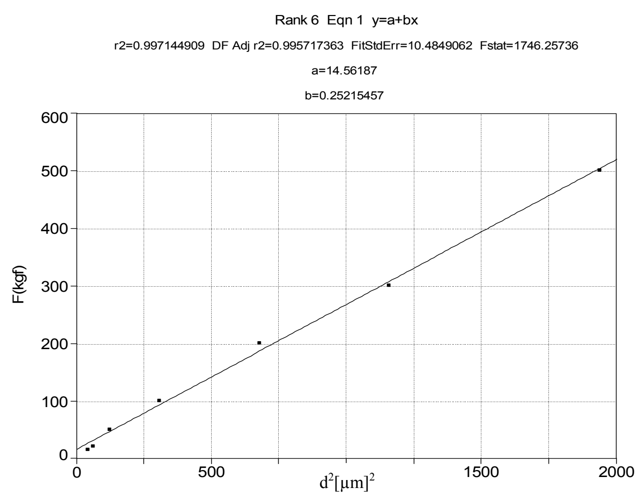

Fig.2 Quadratic plot for a P5S40-tt-300⁰C (Hays-Kendall model F = W + Kd²)

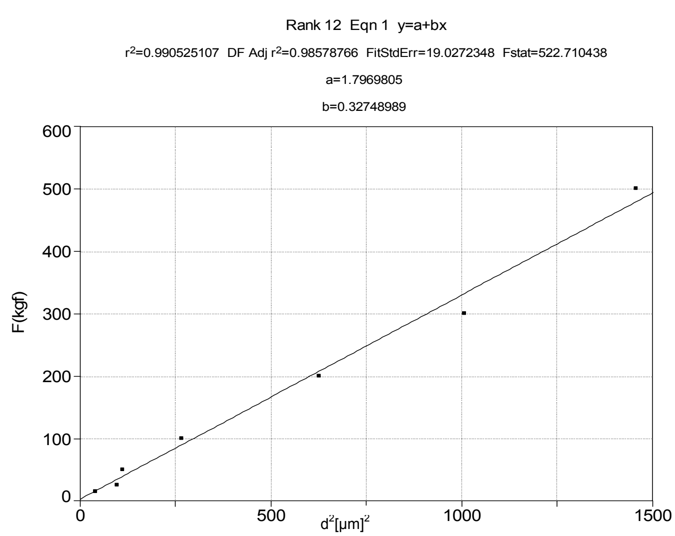

Fig.3: Quadratic plot for a P20S40-tt-300⁰C (Hays-Kendall model F = W + Kd²)

It is worthy to mention that the measured values for d^2 (the square of the verage diagonal of the Vickers indentation) were obtained at various indentation loads (F=15; 25; 50; 100; 200; 300gr.f). It was obtain a very good coefficient r^2 comprised between 0,990 and 0,997 for all composites Ni-P/SiC by treatment to 300^0C.

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