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Factors influencing the accuracy of properties tests of thin layers-substrate systems

J. Koutský

University of West Bohemia, Plzeň, Czech Republic

Abstract: Factors influencing the accuracy of measurements of mechanical and physical-chemical properties of thin layer-substrate system were investigated. Following items were studied: microlocalities, cyclic static indentation, cyclic stretch indentation, gross-section surface after macroindentation loading, accoustic emission signal at stretch test, characteristics of indentors, electrochemical measurements, erosion loading.

Keywords: Technological sciences, Materials engineering, Surface treatment

1. INTRODUCTORY

Exact knowledge of thin layers-substrate system mechanical and physical-chemical properties as well as knowledge of its adhesive-cohesive behaviour are the basic presumptions for technical application of L-S systems. Factors influencing the accuracy of measurements shall be therefore studied precedently.

2. EVALUATION OF MECHANICAL PROPERTIES AND DEVELOPMENT OF THIN COATING SYSTEMS EVALUATION METHODS

2.1.Microlocalities

Evaluation of mechanical properties of thin coated systems is concentrated on complicated and sensitive measurements in microlocalities of basic material and of surface layers. Nanoindentation evaluation methods are mostly used for evaluation of mechanical properties and behaviour of L-S system. Adjustment of mechanical properties measurement of independent surface layers without substrate influence on measurement and comparison of properties and behaviour of surface layers and surface of basic material without coating are required. The measurements are focused on the evaluation of mechanical properties and behaviour of individual structure components (fig. 1, 2). The individual microlocalities can be modified by different processes and thus the changes of the microlocalities due to the individual different processes (F. i. ion bombard) must be investigated (fig. 3).

2.2. Cyclic static indentation

Cyclic nanoindentation and macroindentation process of mechanical loading of different systems of thin layer-substrate are very important with respect to the complex view on the

elastic and plastic deformation relation as well as on the simulation of local repeated load, local fatigue load and step by step changes of surface properties due to the cyclicity of the load.

At macroindentation cycles kinds of load the contribution of thin layers on surface strengthening and on resistance against initiation and propagation of deterioration were proved. Measurement modes with constant and variable force were used (fig. 4).

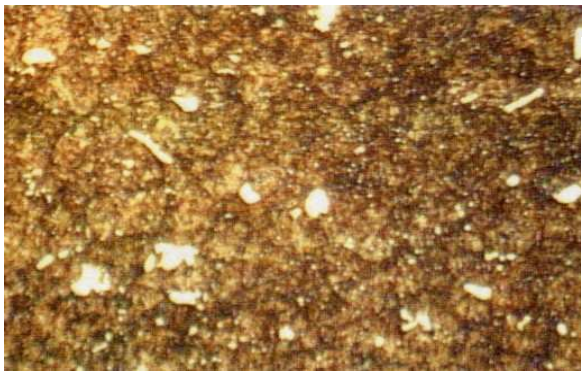

Figure 1. Etched microstructure of high speed steel 19802

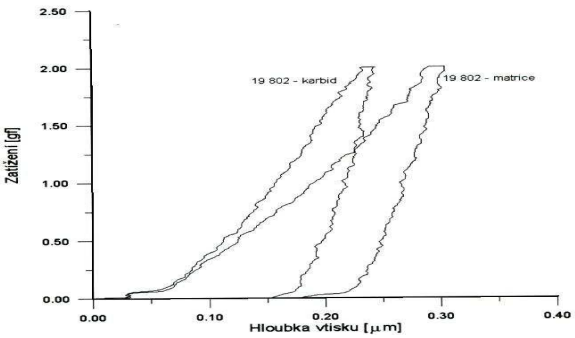

Figure 2. Indentation curves of basic material in different localities, moce 2, loading 2g

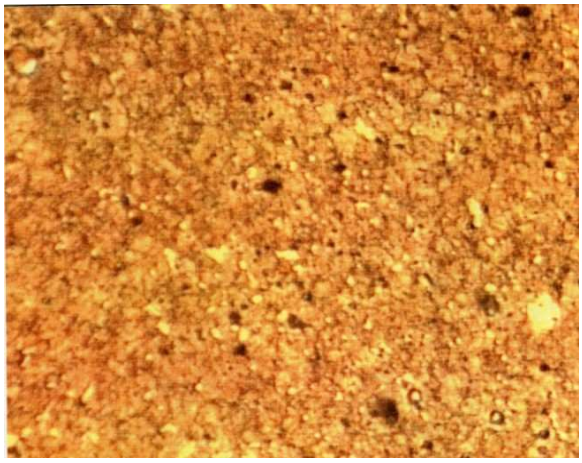

Figure 3. Morphology of surface of steel 19830 bombarded by Ti ions, mode 2, loading 2g

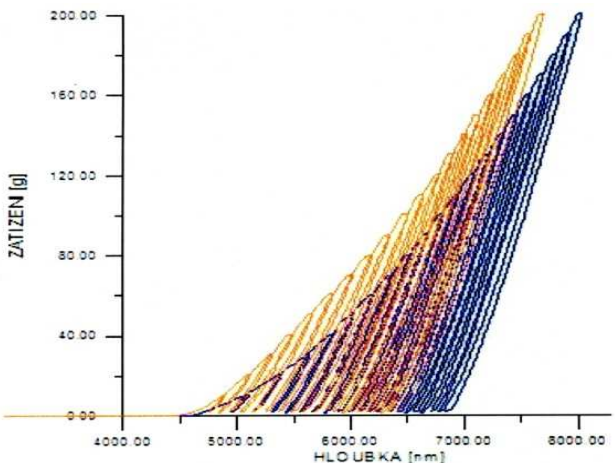

Figure 4. Indentation curves of material 19830, loading 200g, mode 7, (blue-substrate, orange-system).

2.3. Cyclic stretch indentation

Cyclic stretch tests were carried out on some L-S systems with different basic materials. With in the experiments the important portion of cohesive deterioration of basic material below surface layer was found as the main cause of cracking initiation. Metallographic preparation influences also the initiation and propagation of deterioration.

2.4. Cross section surface after macroindentation loading

The deterioration was evaluated as well as from the surface (fig. 5) as from cross section. The deterioration is predominantly initiated by cohesive mechanism below surface layer which is not self-supporting.

2.5. Accoustic emission signal

Accoustic emission signal at scratch test was investigated both on the metallographically prepared surface of basic material and on the thin layer-substrate system. The course of the signal is influenced not only by separation of thin layer from substrate but also by the state of surface, by the modification of ion bombard process, etc. (fig. 6).

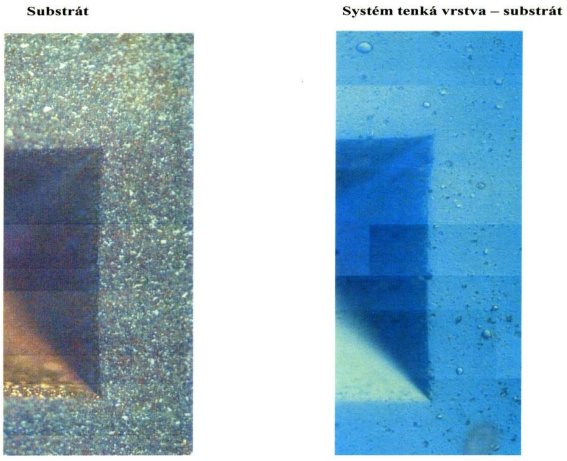

Figure 5. Surrounding area of indentation at indentor loaging of 1875,5 kg on substrate

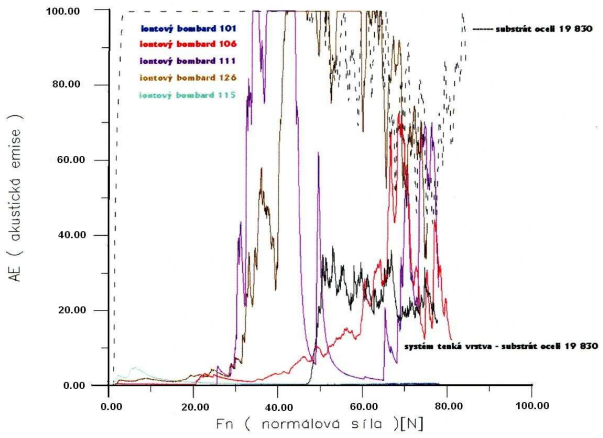

Figure 6. Summarized survey of acoustic emission curve (AE) in dependence on normal force (Fn) of ion bombards of steel 19830

2.6. Negative factors influencing the results of sensitive nanoindentation measurements

Important attention shall be payed to the vibritations. The vibration influence is very meaningfull and can be acting instantly (can be instantly eliminated) or longtermly in dependence on different systems of material with or without thin layer, on different material hardness and loading value, etc. The shape of indentation curves is strongly influenced by vibration.

2.7. Characteristics of indentors

During experiments the indentor is strongly weared. The measurement results are dependent on the indentor characteristics change. After repeated indentor scratch tests indentor geometry is rapidly modified. Indentor wear characteristics during scratch test is following: rappid shift of wear coefficient to higher values of actingnormal force appears as well as rapid shift of acoustic emissionsignal to higher values of normal force.

3. ELECTROCHEMICAL MEASUREMENTS OF THIN LAYERS SYSTEMS

Electrochemistry is used for the evaluation of resistance against corrosion of the surface of the L-S system. It was found that surface properties are improved by coating. Some effect of coppy of corrosion properties of basic material with high corrosion resistance appears (fig. 7). It was found that the changes of surface mechanical properties are also evident in locations where no clear deterioration of surface exists.

4. EROSION LOADING

Erosion loading of coated turbine blades was simulated on erosion stands in Škoda-Power plant. The positive influence of thin coating is documented on the fig. 8.

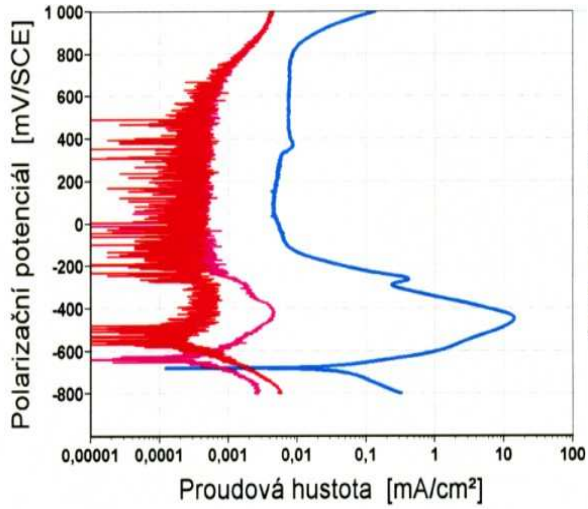

Figure 7. Polarization curves of steel 11523 (blue) and steel 11523 with TiN layer of 3 μm and 4 μm depth (red) in natrium citrate with limon acid solution.

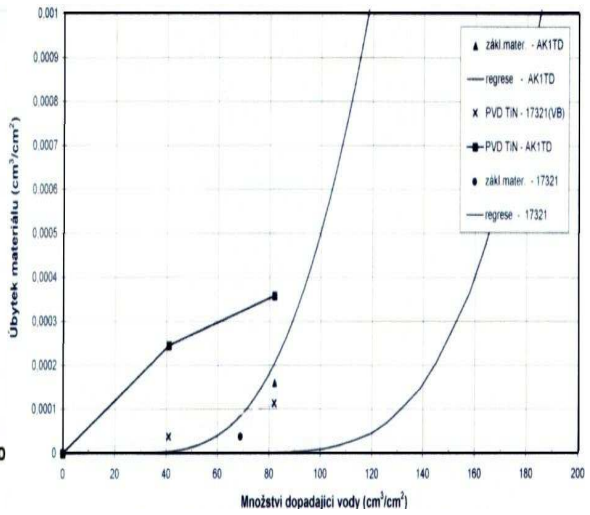

Figure 8. Erosion curves for different basic materials and systems with thin layer.

5. SUMMARY

Described research works complete our knowledge of individual preparatory phases before deposition process, individual phases of deposition process to optimalize real material systems.

Knowledge of analytic methods of mechanical properties as well as of behaviour of thin layer-substrate systems with respect to repeated mechanical loading and development of initiated deterioration was extended. Accuracy methods of mechanical properties and behaviour find application in other areas to (like evaluation of specific materials and degradation and aging processes).