POLISH ACADEMY OF SCIENCES - MATERIALS SCIENCE COMMITTEE
SILESIAN UNIVERSITY OF TECHNOLOGY OF GLIWICE
INSTITUTE OF ENGINEERING MATERIALS AND BIOMATERIALS
ASSOCIATION OF ALUMNI OF SILESIAN UNIVERSITY OF TECHNOLOGY
Conference Proceedings
11th INTERNATIONAL SCIENTIFIC CONFERENCE
ACHIEVEMENTS IN MECHANICAL & MATERIALS ENGINEERING

Step by step evaluation of combination stress of the thin film – substrate system*

R. Reindl, J. Koutský, I. Štěpánek, R. Poskočil, M. Sosnová, K. Jačková

Faculty of Mechanical Engineering, University of West Bohemia
Univerzitní 22, Plzeň, Czech Republic

Step by step evaluation is method based on an aproximation of combination stress in laboratory conditions. The changes of the adhesive – cohesive behaviour of the thin film – substrate system were observed in specific conditions. There were analysed TiN coatings deposited by reactive arc evaporation and substrate was high speed steel. Systems were tested in two combinations of stresses. First combination was temperature and mechanical stress, second combination was corrosion and mechanical stress. Experimental data were analysed by methods of image analysis.

1. INTRODUCTION

In the aproximation of real behaviour into laboratory conditions is important for evaluation of surfaces to observe fractures and their modifications in combination stresses [1]. It is important to predict main kinds of stresses and analyse their influence on properties of surface.

There are some different kinds of experiments for evaluating the surfaces in conditions of combination stress. These conditions can be usually set up with one of combinations of thermal, corrosion or mechanical stresses [2]. The evaluation could be one of following – step by step evaluation or simultaneous stress testing [3]. Now we are concentrated on step by step evaluation. The main attention by evaluation of cohesive and adhesive–cohesive behaviour is given by behaviour during scratch test measuring [4][5].

2. EXPERIMENTAL DETAILS

Two different types of TiN coatings were deposited by reactive arc evaporation in vacuum. The substrate was high speed steel for all the specimens. Before deposition, the substrate was cleaned by ion bombardment.

Deposition parameters were substrate bias – 250 V and temperature of the substrate 450 °C. The thickness of coatings were mesured by calotest. Thickness of the first type of coating was 0.6 µm and thickness of the second type was 1.2 µm.

The principle of the step by step evaluation is cyclic loading of the system by mechanical, corrosion or thermal stress or by their combination and evaluation of specimen surface before

* Authors participate in the CEEPUS No PL-013/02-03 project headed by Prof. L.A. Dobrzański.

and after each cycle [6]. In our case, there were combined cycles of thermal and mechanical loading in the first part of the experiment and cycles of corrosion and mechanical loading in the second part of experiment.

Thermal loading was simulated by 15 min heating on temperatures 200, 400, 500, 600 and 700 °C. Corrosion cycle was 20 min in H_2O. Mechanical loading was simulated by Rockwell diamond indentor by scratching load from 0 to 80 N. There were evaluated failures around scratch and changes of properties in load–modificated areas. Evaluation was performed by methods of the image analysis.

3. RESULTS AND DISCUSSION

3.1. Thickness of coatings

The thickness of coatings was measured by calotest and evaluated by methods of image analysis. In fig. 1 one can see changes on coated surfaces after 700 °C heating. A thinner coating is fully degraded by oxidation. On a specimen with thicker coating one can see oxidated layer of the coating. That means, the original system was transformed to a new system and changed its properties and ahesive – cohesive behaviour.

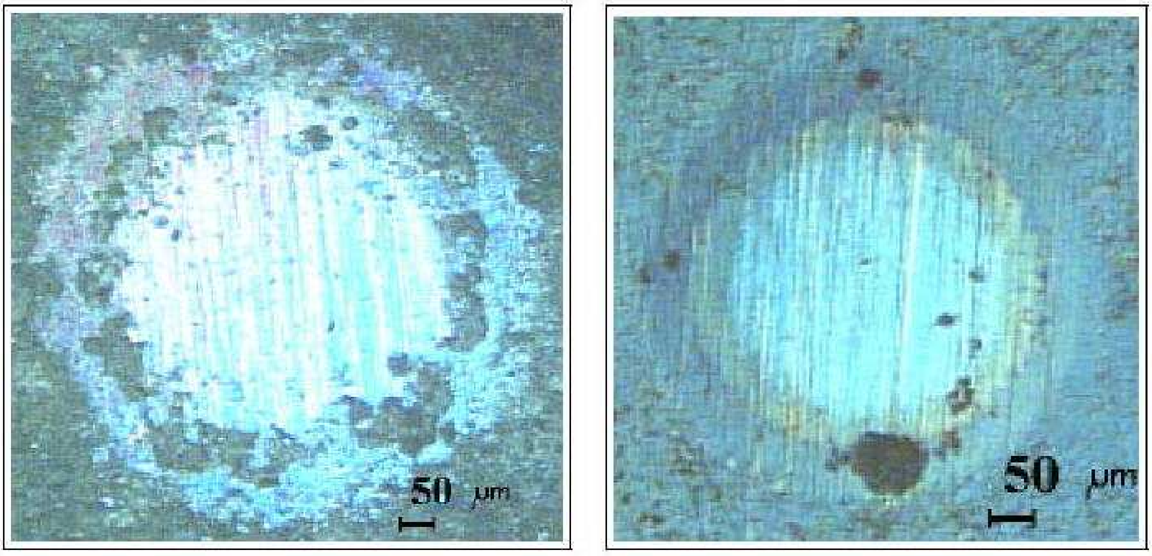

Fig.1: Calottes on the specimens after 700 °C heating. On the left there is a specimen with thickness of the coating 0.6 μm and on the right a specimen with thickness of the coating 1.2 μm

3.2. Thermal – mechanical loading

Cohesive failuring of substrate surface without coating increases with increasing temperature. The reason is a rise of oxidic layer on surface.

Cohesive failuring of system with the first type of coating shows, that coating slows down growth of failures. At the highest temperatures is coating fully–oxidated and cohesive behaviour of the system is similar to behaviour of substrate without coating.

Cohesive failuring of system with thicker coating is the lowest of all tested systems and is given by oxidic layer in the coating.

A typical character of failures after thermal loading cycles 500 °C and 700 °C is shown in figures 2 and 3.

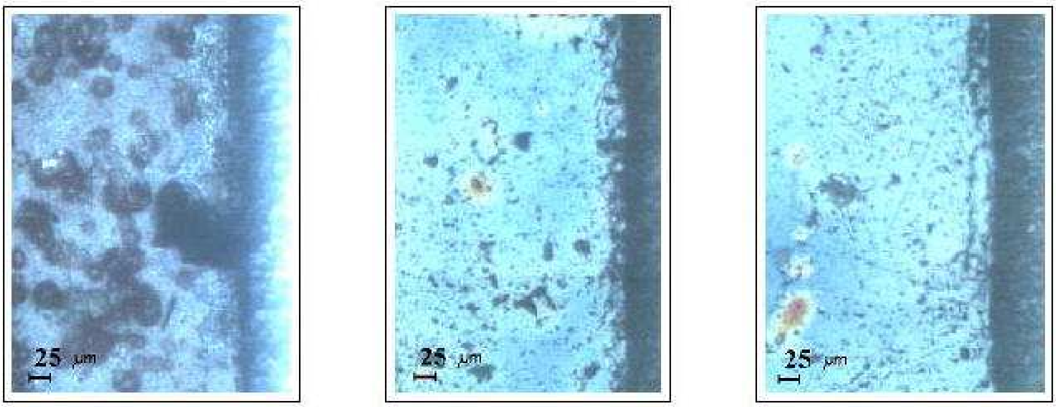

Fig.2: Comparison of the surfaces after 500 °C heating, left picture is surface without coating, in the middle is surface with thinner coating and right is surface with thicker coating

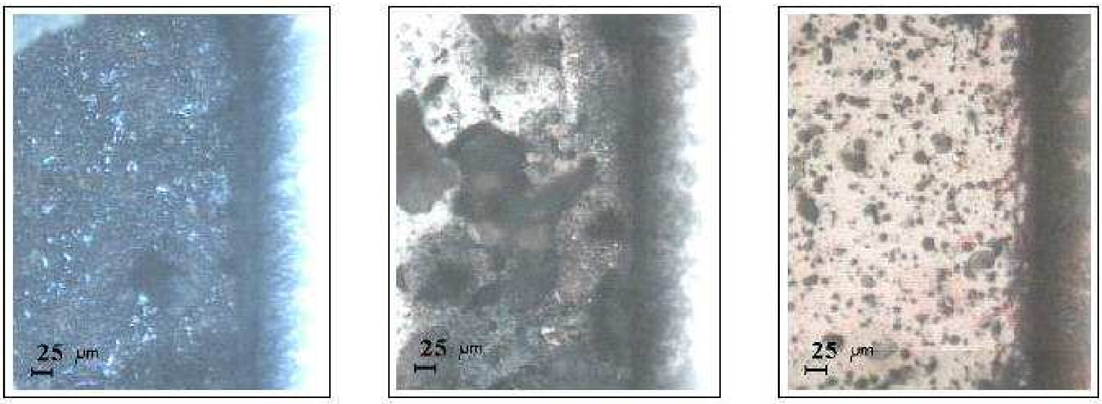

Fig. 3: Comparison of surfaces after 700 °C heating, left picture is surface without coating, in the middle is surface with thinner coating and right is surface with thicker coating

3.3. Corrosion – mechanical loading

Corrosion on all specimens was non-uniform. That complicates comparising and evaluating of influence of corrosion and mechanical loading on surface properties. We can evaluate just only in local areas of surface. We can see, that in areas with corrosion are failures little different, it means, corrosion products change cohesive behaviour of surface.

On specimens with the first type of coating, we can see in corrosion areas both changes of the cohesive and adhesive behaviour.

Surface with thicker coating results better resistace against corrosion and mechanical loading, mainly in cohesive behaviour. Changes of adhesive behaviour are similar to previous case.

4. CONCLUSIONS

The analysis of mechanical properties of systems thin film–substrate is important, but gives very small information for prediction of behaviour in practice conditions. The evaluation of combination stress is better aproximation of real conditions in laboratory. The step by step evaluation gives new possibilities to characterize initiation of fractures and their next expansion. It gives better possibilities for optimalisation of deposition parameters.

This experiment shows behaviour of surface systems in corrosion–mechanical and in thermal–mechanical stress conditions. Results show, that TiN coating improves behaviour of surfaces in these conditions and the thickness of coating is important parameter for optimalisation of deposition process.

The paper is presented in the range of solution of project exploratory intention University of West Bohemia MSM 23 21 00 006: Research and development innovation, construction, technology and material engineering machine – industries products.

REFERENCES

1. Štěpánek, MATRIB'00, Vela Luka, Croatia, 2000, 335-342
2. Z. Bartůšková and I. Štěpánek, MATRIB'00, Vela Luka, Croatia, 2000, 23-30
3. Štěpánek, MATRIB'01, Vela Luka, Croatia, 2001, 261-268
4. Štěpánek, O. Bláhová, Š. Šimůnková and J. Brůnová, Method for analysis properties and behaviour of thin hard films, ICSFS'98, Copenhagen, 1998
5. J. Brůnová and I. Štěpánek, Analysis wear resistant of thin films by scratch tester, Junior–Euromat'98, Lausanne, 1998
6. R. Reindl, I. Štěpánek and K. Jačková, MATRIB'02, Vela Luka, Croatia, 2002, 197–203