



## How to cite this article:

Author: Maciej Jan Kupczyk

Title of article: „Ocena możliwości zwiększenia siły adhezji twardych powłok do ostrzy skrawających poprzez ich nagrzewanie laserowe” (“Estimation of possibilities of increase of adhesion of hard coatings to cutting edges by its laser heating”)

Mechanik, Vol. 91, No. 8-9 (2018): pages 680-682

DOI: <https://doi.org/10.17814/mechanik.2018.8-9.106>

# Estimation of possibilities of increase of adhesion of hard coatings to cutting edges by its laser heating

## Ocena możliwości zwiększenia siły adhezji twardych powłok do ostrzy skrawających poprzez ich nagrzewanie laserowe

MACIEJ JAN KUPCZYK\*

**Evaluation of the possibilities of increasing of adhesion force (values of the critical load measured by the scratch test) of hard coatings to cutting edges made of cemented carbides by their laser heating was a purpose of researches.**

**KEYWORDS:** cutting edges, hard coatings, laser heating

Due to the very significant influence of adhesion force of the coating on the substrate on the operational quality [1-9], especially coated cutting tools, the assessment of the possibility of increasing the adhesion of selected hard coatings to replaceable carbide cutting plates by their laser heating was evaluated. The presented studies are a continuation of work on obtaining the highest adhesion of hard coatings to the cutting tools' blades [6].

### Basic research conditions

The adhesion measurements (critical load  $L_c$  values measured using the scratch test) were made on the basis of the assessment of the acoustic emission level and the vibration signal, measured by the amplitude level of acceleration  $A_{cc}$  ( $m \cdot s^{-2}$ ) in the frequency band tested (fig. 1). The device for measuring adhesion was equipped with two independent measuring paths, i.e. with a piezoelectric accelerometer and a sonometer [7].

On the basis of the results of research on the influence of internal parameters of the scratch test on the critical load value presented in [6], the following parameters were adopted:

- scratchig speed  $dx/dt = 7.5 \text{ mm} \cdot \text{min}^{-1}$ ,
- loading rate  $dL/dt = 300 \text{ N} \cdot \text{min}^{-1}$ ,
- ratio  $dL/dx = 40 \text{ N} \cdot \text{mm}^{-1}$ ,
- radius of the stylus tip  $R = 0.20 \text{ mm}$ .

Such values of the scratch test internal parameters were considered the most favorable in terms of the following criteria [6]:

- measurement time,
- scatter of measurement results,
- $L_c$  variability in the  $dL/dt$  function for the assumed  $dx/dt$  value,
- $L_c$  variability in the  $dx/dt$  function for the assumed  $dL/dt$  value,

- $L_c$  variability in the  $dL/dx$  function for the assumed  $R$  value.

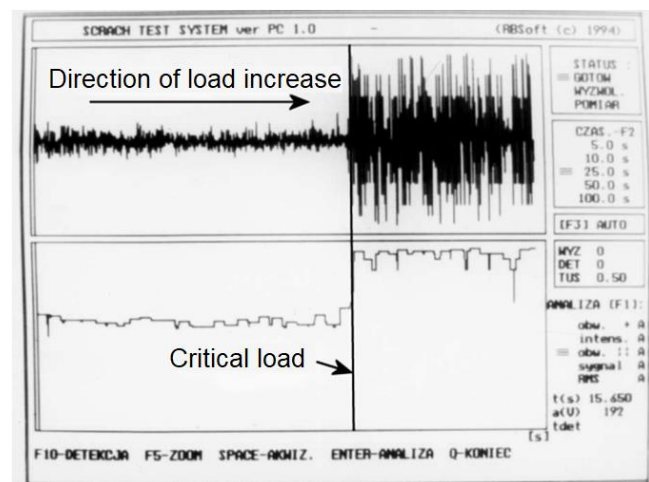


Fig. 1. Screen of the monitor with an example of the vibration signal generated during scratching the sample with a hard coating (a rapid increase in the amplitude of the vibration accelerations is a sign of loss of adhesion of the coating to the substrate)

In the adhesion force tests, interchangeable machining plates of the NTH2 type SNGN120408 type (with tool orthogonal clearance angle  $\alpha_0 = 0^\circ$ ), i.e. of H20S cemented carbides (M10-M25, K05-K25) coated with a hard two-layer TiC+TiN coating using the technique CVD (Baidonit plants). These plates are intended for roughing and shaping (medium fine) cast irons. They are also suitable for machining heat resisting steel, creep-resisting steel, as well as light alloys and plastics [5].

Said cutting blades were subjected to laser heating using the CO<sub>2</sub> TLF 2600T technology laser installed in the Laser Technology Laboratory of the Institute of Mechanical Technology. A technological laser coupled with a lathe is shown in fig. 2.

In the laser cutting process of the cutting inserts, the following values of the machining parameters were used:

- beam diameter (track width)  $\varnothing = 4 \text{ mm}$ ;
- beam power:
  - $P_1 = 15\%$  of the maximum laser power,
  - $P_2 = 20\%$  of the maximum laser power,
  - $P_3 = 25\%$  of the maximum laser power,
  - $P_4 = 30\%$  of the maximum laser power,
  - $P_5 = 40\%$  of the maximum laser power;

\* Prof. dr hab. inż. Maciej Jan Kupczyk (maciej.kupczyk@put.poznan.pl) – Instytut Technologii Mechanicznej Politechniki Poznańskiej

- power density:
  - $q_1 = 3105 \text{ W/cm}^2$ ,
  - $q_2 = 4140 \text{ W/cm}^2$ ,
  - $q_3 = 5175 \text{ W/cm}^2$ ,
  - $q_4 = 6210 \text{ W/cm}^2$ ,
  - $q_5 = 8280 \text{ W/cm}^2$ ,
- scanning speed:  $v_f = 1.28 \text{ m/min}$ .

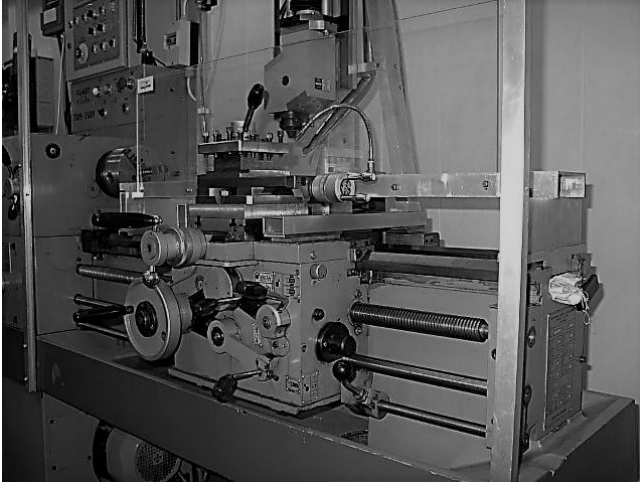


Fig. 2. Lathe with the installation that feeds the laser beam to the machining zone (with the head concentrating the laser beam), the desktop and control cabinets that are part of the laser heating station for samples

### Results of basic research

The table presents the results of adhesion force tests (critical load values measured in the scratch test) under various conditions of the laser heating process.

**TABLE. Results of adhesion tests of TiC+TiN coatings – non-heated and laser-heated – for H<sub>2</sub>O<sub>2</sub> cemented carbide substrates (average values from five measurements)**

Heating conditions (% of maximum laser power)	Critical load value $L_c$ , N
0	$34.5 \pm 4.9$
15	$40.7 \pm 6.3$
20	$75.1 \pm 8.0$
25	Surface cracks of cutting inserts
30	Surface cracks or insert decohesion
40	Insert decohesion (cracking throughout)

### Verification tests

To confirm the results of adhesion force (critical load) tests measured with the scratch test based on the acoustic and vibration signal evaluation, scratch observations were performed using:

- scanning microscopy (images created by secondary electrons; SE),
- profilometer (3D images),
- x-ray microanalysis (surface qualitative microanalysis).

It should be emphasized that the comparison of the adhesion force results obtained based on the evaluation of acoustic and vibration signals with critical load values  $L_c$  (critical load, N), determined by scanning microscopy or X-ray microanalysis, is only possible if there is damage to the coating in the form of exfoliation revealing the substrate [6]. Such a case took place in the discussed studies.

Measurement of the scratch length was carried out automatically on a computer-assisted scanning microscope VEGA – TS 5135 from the English company TESCAN – Digital Microscopy Imaging, at the Institute of Materials Engineering at the Poznan University of Technology.

Fig. 3 shows SE images of scratching the cutting insert grade NTH2(H<sub>2</sub>O<sub>2</sub>+(TiC+TiN)) with automatic measurement of the length of the section on which the substrate was exposed.

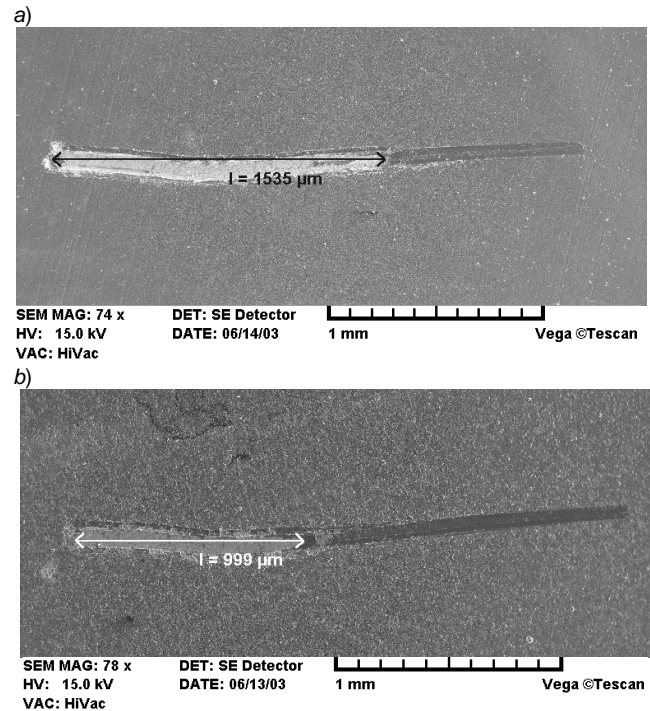


Fig. 3. Example SE image of scratching TiC+TiN coating deposited on H<sub>2</sub>O<sub>2</sub> cemented sintered carbide: a) laser-free, b) laser-heated ( $P_1 = 15\%$  of maximum laser power)

Fig. 4 presents negative 3D images of scratches made with the use of a profilometer.

Fig. 5 shows microanalysis of the qualitative content of titanium, cobalt, and tungsten on the surface of the plate with TiC+TiN coating deposited on H<sub>2</sub>O<sub>2</sub> cemented carbide, heated by laser ( $P_1 = 15\%$  of the maximum laser power).

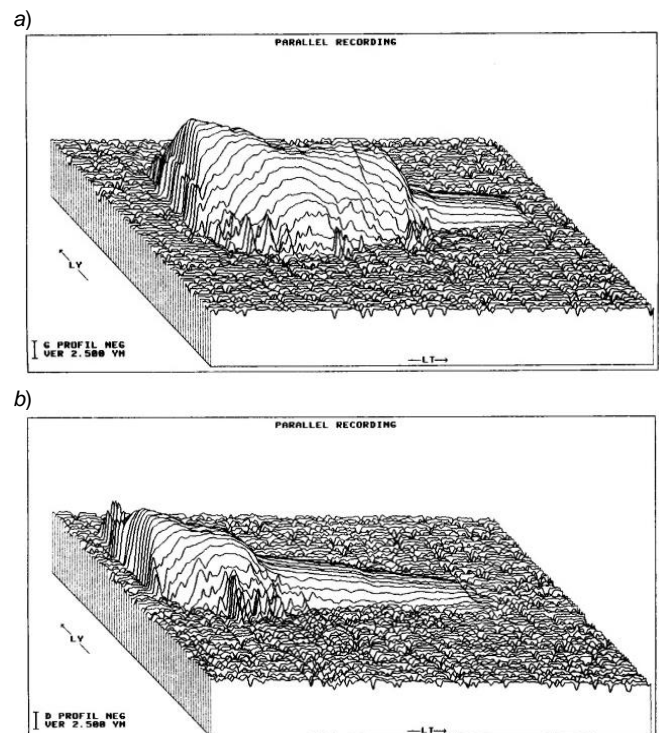


Fig. 4. Negative 3D images of scratching TiC+TiN coating deposited on H<sub>2</sub>O<sub>2</sub> sintered carbide: a) laser-free, b) after laser heating ( $P_2 = 20\%$  of the maximum laser power)

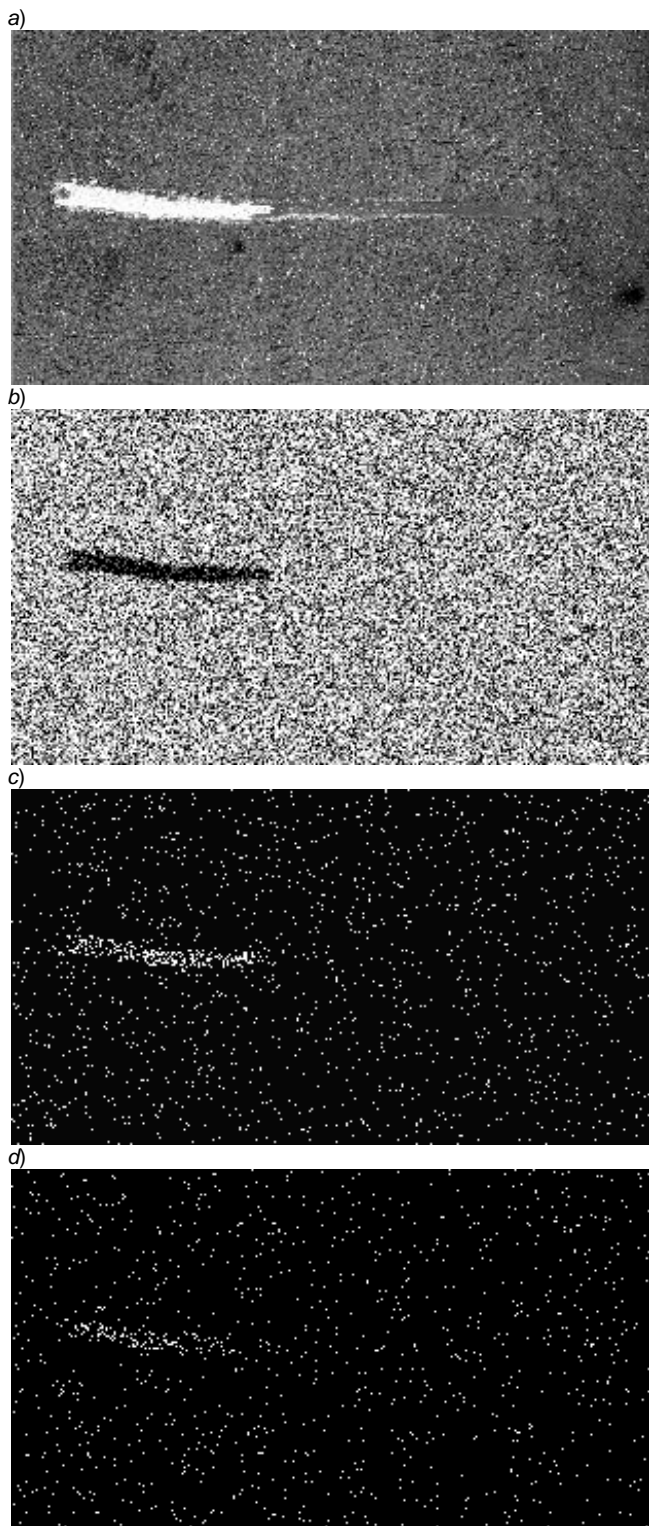


Fig. 5. Sample images: a) SE and surface microanalysis of qualitative content: b) titanium, c) cobalt, d) tungsten on the surface of the plate with TiC+TiN coating deposited on H20S sintered carbide, heated by laser ( $P_1 = 15\%$  of maximum power laser)

Observations made with the use of scanning microscopy of the scratched coatings unambiguously confirm that the measured critical load value determined on the basis of an acoustic signal corresponds to the detachment of the TiC+TiN coating from the substrate.

Negative 3D images, made using a profilometer, also confirmed the results of measurements using a sonometer and piezoelectric accelerometer (measurement of the amplitude of vibration accelerations) critical load  $L_c$  values, similar to images of surface microanalysis of the qualitative content of titanium, cobalt and tungsten.

## Conclusions

On the basis of tests of adhesion force of a two-layer CVD coating on exchangeable carbide cutting inserts, it was found:

- significant increase in the adhesion of the TiC+TiN coating to the H20S cemented carbide substrate after laser heating (from  $L_c$  from 34 N to 75 N) for the 20% maximum laser power used (power density  $4140 \text{ W/cm}^2$ );
- heating at 25, 30 and 40% of the maximum laser power leads to surface cracks or decohesion of the cutting insert.

It follows that only under strictly defined conditions of laser heating can a significant increase in adhesion of hard anti-wear coatings be applied to sintered carbide substrates. The positive result obtained after laser heating indicates the need to undertake similar tests using other materials, which are now widely used as coatings deposited on cutting blades.

Research should also be continued to determine the effect of laser heating on the properties of coatings.

The author gives thanks to dr. inż. A. Cellary, dr. inż. M. Jankowiak, dr. inż. Karol Józwiak and I. Nowak from the Poznań University of Technology for providing research equipment.

The work was carried out with funds from research project No. 02/22/DSPB/1433DS.

## REFERENCES

1. Burakowski T. „Rozważania o synergizmie w inżynierii powierzchni”. *Physico-Chemical Mechanics of Materials*. 1 (2000): pp. 639.
2. Burnett P.J., Rickerby D.S. “The scratch adhesion test: an elastic-plastic indentation analysis”. *Thin Solid Films*. 157 (1988): pp. 233.
3. Greene J.E., Pestes M. “Adhesion of sputter-deposited carbide films to steel substrates”. *Thin Solid Films*. 37 (1976): pp. 373.
4. Hammer B., Perry A.J., Laeng P., Steinmann P.A. “The scratch test adhesion of TiC deposited industrially by chemical vapour deposition on steel”. *Thin Solid Films*. 96 (1982): pp. 45.
5. Katalog „Płytki wielostrzowe”. Baildonit, Huta Baildon.
6. Kupczyk M. „Jakość technologiczna i użytkowa ostrzy skrawających z powłokami przeciwzużyciowymi”, monografia 232. Seria: *Rozprawy*, No 320. Poznań: Wyd. Politechniki Poznańskiej, 1997.
7. Kupczyk M., Wieczorowski K. „Zespół do pomiaru przyczepności do podłoża warstw przeciwzużyciowych zwłaszcza osadzonych na powierzchniach narzędzi skrawających”. Patent Pat-981/PP/1993 oraz P 301807/1994.
8. Lee G.H., Cailler M., Kwon S.C. “Adhesion studies of magnetron-sputtered copper films on nickel substrates”. *Thin Solid Films*. 186 (1990): pp. 21.
9. Perry A.J. “The adhesion of chemically vapour-deposited hard coatings to steel – the scratch test”. *Thin Solid Films*. 78 (1981): pp. 77.
10. Tang J., Zabinski J.S., Bultman J.E. “TiC coatings prepared by pulsed laser deposition and magnetron sputtering”. *Surface and Coatings Technology*. 91 (1997): pp. 69.

Translation of scientific articles, their computer composition and publishing them on the website [www.mechanik.media.pl](http://www.mechanik.media.pl) by original articles in Polish is a task financed from the funds of the Ministry of Science and Higher Education designated for dissemination of science.



Ministry of Science  
and Higher Education

Republic of Poland

