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THE MATHEMATICAL MODEL OF ADHESIVE FRACTURE OF SUPERLATTICE COATING

***Abstract**: The research results of adhesion characteristics of AlN/CrN coating (superlattice) are presented in the article. The images analysis of coating fracture when linear scratching on the measuring equipment "Micro Combi Tester" was performed. The mathematical model of adhesive fracture of AlN/CrN coating was obtained on the basis of calculated values of the vertical force applied to the indenter, the friction coefficient, the friction force, the scratching length and the penetration depth of the indenter.*

***Key words**: coating, a scratch, adhesion, a force, the indenter.*

***Language**: English*

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Introduction

A cutting tool is subjected to wear when machining of various workpieces. This process leads to changing of sizes of a cutting part of the tool, and, accordingly, to increasing of the sizes of the workpiece. Different protective coatings applied to the cutting part of the tool (e.g., throw-away carbide inserts) to increasing durability.

Coatings can be decorative, hardsurfacing and antifriction. Antifriction coatings are used for the blade cutting tools. Multilayer ceramic coating AlN/CrN (superlattice) has high properties. The total thickness of all coating layers is several micrometers. Adhesion to surfaces of the cutting tool is one of the main indicators of these coatings. Adhesive strength of coating is evaluated by the scratch testing (scratching with the indenter).

Materials and methods

The research of adhesive strength of superlattice coating [1 – 10] was performed in the laboratory. AlN/CrN coating was applied to a sample made of 1.3339 high speed steel (EN). Coating application was performed on the equipment UniCoat 600 SL+ by the method of physical vapour deposition (PVD). The coated sample was subjected to linear scratching with the special indenter on the equipment "Micro Combi Tester" NHT-O-M D-000X (CSM Instruments). The conditions of the research of adhesive characteristics of AlN/CrN coating are presented in the table 1.

Table 1. The conditions of the research.

Scratching type	Linear scratching	**Load type**	Progressive	**Initial load, N**	0.1
Final load, N	29	**Load speed, N/min**	18.06	**AE Sensitivity**	5
Scanning load, N	0.03	**Speed, mm/min**	5	**Length, mm**	8
Position X, mm	60.481	**Position Y, mm**	39.772	**Fn contact, N**	0.03
Fn speed, N/s	5	**Fn speed of removal, N/s**	10	**Speed of zoom, %/s**	2
Dz sensor	Standard range	**Indenter type**	Rockwell	**Serial number of indenter**	I-159
Indenter material	Diamond	**Radius of indenter, µm**	100		

Results and discussion

The process of linear scratching of AlN/CrN coating was recorded on a digital video camera built into the equipment. The some images of the received scratch showing adhesive fracture of AlN/CrN coating are presented in the Fig. 1. The lines on each image are the distances traveled by the indenter. The images were obtained on the microscope when using of the 20x lens. The dimensions of each image were 330×249 micrometers.

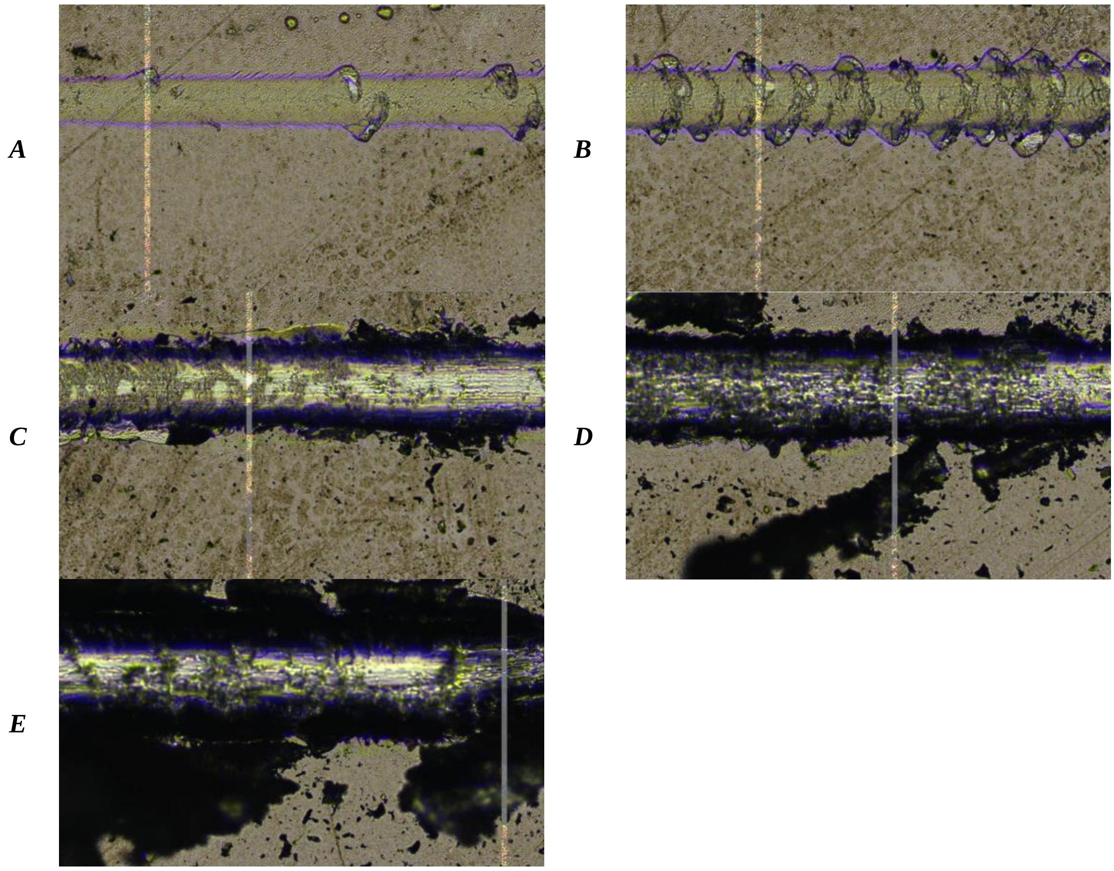

Figure 1 – The images of the received scratch on coating of the sample: *A* – coating fracture at the length of 1.2 mm; *B* – coating fracture at the length of 2.1 mm; *C* – coating fracture at the length of 3.1 mm; *D* – coating fracture at the length of 4.6 mm; *E* – coating fracture at the length of 7.95 mm.

Gradual indentation of the diamond indenter leads to partial fracture of coating. Only the surface layers of AlN/CrN coating are fractured in the vertical load application range of 0.1 – 6 N. Complete fracture of coating with extensive delaminations occurs in the vertical load application range of 6 – 24 N. Oscillations of the indenter, caused by intense delamination of coating, occur at the vertical load of more than 11 N. The friction coefficient of AlN/CrN coating decreases with increasing of the vertical load, and the friction force increases slightly.

Adhesive strength (τ_o) of AlN/CrN coating can be presented by the formula (1):

$$\tau_o = -816.8822 + 4303.5798\mu - 213.9251l + 18039667.6556 \times 10^4 F_v + 4343.6199 F_{fr} - 0.05724h, \quad (1)$$

where μ is the friction coefficient; l is the scratching length, mm; F_v is the vertical force, N; F_{fr} is the friction force, N; h is the penetration depth, nm.

Conclusion

Complete delamination of AlN/CrN coating from the sample surface occurs at 12 N. The friction coefficient of coating practically does not change when the scratch testing and is 0.02 – 0.022. The applied vertical force and the friction force significantly affect on adhesive strength of AlN/CrN coating in accordance with the obtained regression equation.

References:

1. Chemezov, D. A. (2013). Adhesive strength of coating AlN/CrN (superlattice). *"Applied Sciences and technologies in the United States and Europe: common challenges and scientific findings": 2 International Scientific Conference*, 143-145.
2. Bukarev, I. M., & Zhdanov, A. V. (2012). Investigation of the effect of process parameters to wear magnetron deposition coatings CrN/AlN. *Digital scientific magazine «Modern problems of science and education», №2*.
3. Musil, J., Kunc, F., Zeman, H., & Polakova, H. (2002). *Surface & Coatings Technology, no. 154*, 304-313.
4. Lee, S. Y. & Lee, S. Y. (2006). Comparative Evaluation of TiN/CrN, AlN/CrN, TiAlN/CrN Multilayer Films for the Use of Semi-Solid Processing of Cu Alloys. *Solid State Phenomena*, *Vols. 116-117*, 124-127.
5. Gleiter, H. (2000). Nanostructured materials: basic concepts and microstructure. *Acta Materialia, Vol. 48, No. 1*, 1-29.
6. Mayrhofer, P. H., Mitterer, Ch., Hultman, L., & Clemens, H. (2006). Microstructural design of hard coatings. *Prog. Mater. Sci.*, *Vol. 51*, 1032-1114.
7. Mitterer, C., Mayrhofer, R. N., & Musil, J. (2005). Thermal stability of PVD hard coatings. *Vacuum*, *Vol. 71*, 279-284.
8. Tien, Ch. K., Duh, J.-G., & Lee, J.-W. (2007). Oxidation behavior of sputtered CrN/AlN multilayer coatings during heat treatment. *Surf. and Coat. Tech.*, *Vol. 201*, 5138-5142.
9. Park, L.-W., Kang, D. S., Moore, J. J., & Kwon, S. C. (2007). Microstructures, mechanical properties, and tribological behaviors of Cr-Al-N, Cr-Si-N, and Cr-Al-Si-N coatings by a hybrid coating system. *Surf. and Coat. Tech., Vol. 201*, 5223-5227.
10. Bunshan, R. F. (1994). Handbook of Deposition Technologies for Films and Coatings. *Noeys Publications, Park Ridge*, 1078 p.