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The use of experimental methods and computer simulations to determine the stresses of coatings obtained in the PVD process on sintered tool materials

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Introduction

The development of a numerical model of tools covered with coatings in the PVD process using the finite element method, based on the results of experimental research, makes it possible to predict their properties. Computer simulations can replace time-consuming and costly experimental research and technological trials.The simulated model was made in the Solid Works program and is shown in Figures No. 1 and No. 2. The first one shows the substrate and two coatings from the base, and the second shows the model with imposed boundary conditions, i.e. stresses and restraints.

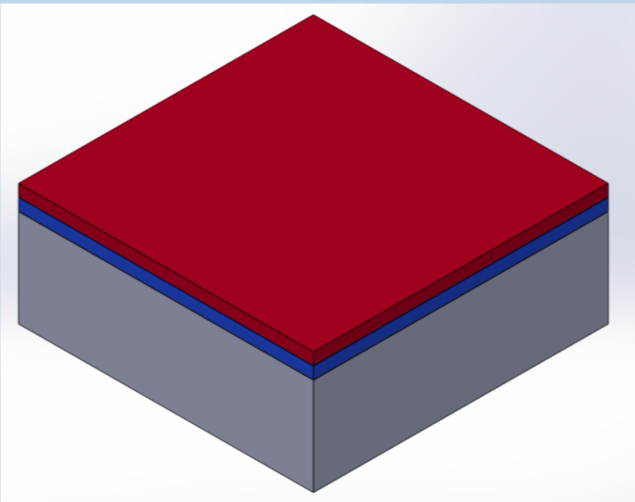

Fig. 1. Geometric model with two coatings.

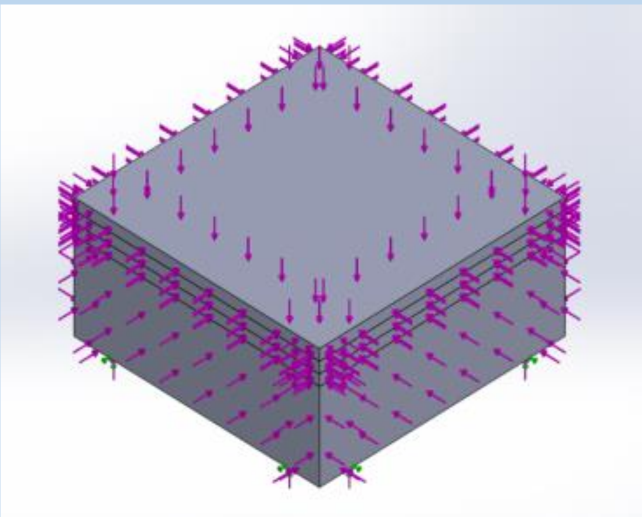

Fig. 2. Geometric model with applied boundary conditions.

X-ray qualitative phase analysis carried out in the Bragg-Brentano geometry confirmed that on the analyzed substrate of tool ceramics based on cermet (T130) and a TiN+(Ti,Al,Si)N coating was produced ,. Due to the overlapping of the reflections of the substrate material and the coating(s) in most cases, it was not possible to perform a full FRO analysis for the applied symmetric Bragg-Brentano geometry. Texture analysis allows to conclude, based on the qualitative analysis of registered single pole figures, that the distinguished growth plane is a plane from the {111} family. Tension measurements of the TiN+(Ti,Al,Si)N coating on a cermet substrate were carried out using the $\sin 2\psi$ method based on the reflection analysis (311). The angular positions of the recorded reflections were determined by the Gaussian curve fitting method. The results of this analysis are shown in Figure 3.

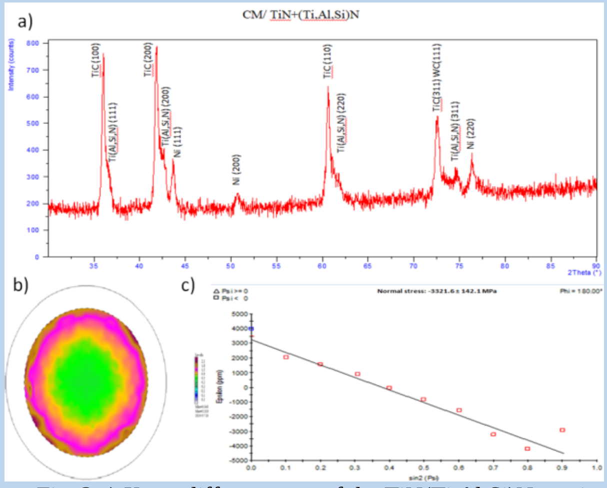

Fig. 3 a) X-ray diffractogram of the TiN(Ti,Al,Si)N coating on the CM - Cermet substrate, b) Polar figure (311) of the TiN+(Ti,Al,Si)N coating, c) Changes in the epsilon (ppm) value determining deformation of the crystallographic lattice of the TiN+(Ti,Al,Si)N coating as a function of $\sin 2\Psi$ of the coating

Results and discussion

Figure 4 shows the images of the topography of the surface of the analyzed coating obtained using the AFM microscope. Based on the observation of the surface topography of the analyzed coatings, it is difficult to indicate the difference between the individual images of the analyzed coatings, which was reflected in the low values of the roughness parameter. Observations of the surface topography using AFM microscopy methods show that the characteristic ends of the columns forming the coating observed on the surface are in the shape of inverted pyramids, cones or craters.

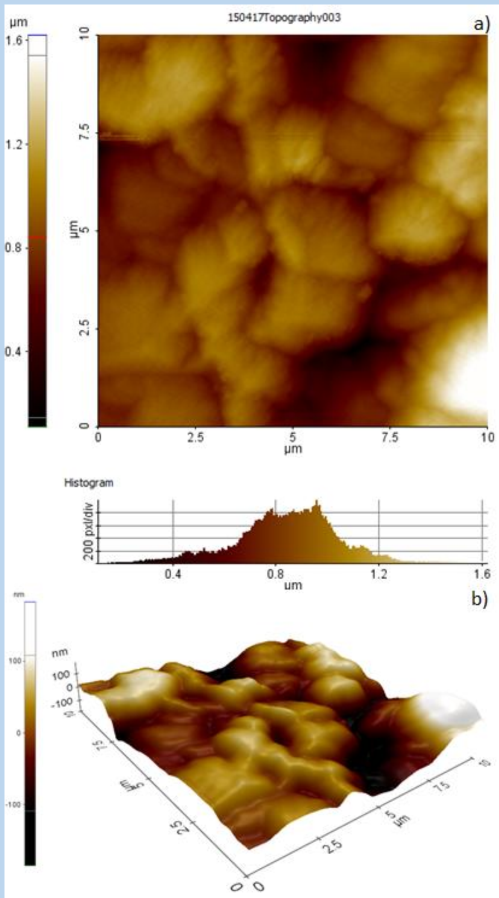

Fig. 4. Image of the surface topography of the TiN+(Ti,Al,Si)N coating obtained on a CM substrate (AFM microscope, scanning range 10x10μm, a) 2D view, b) 3D view).

Figure 5 presents the obtained results of numerical analysis using the finite element method, compiled as color maps of stress distribution in single-layer, double-layer and three-layer coatings on the basis of sintered carbide, cermets and oxide tool ceramics. Numerical analysis showed in all cases the presence of compressive stresses both in the outer and in the middle shell. The creation of compressive stresses in the surface layer (Fig. 9c) can prevent the formation of cracks. However, too much compressive stress can lead to adhesive wear. Attention should be paid to the relationship between the stress value and the microhardness of the surface layer, showing that the greater the compressive stress value, the greater the hardness of the obtained layer. As a result of the tests, it was found that in the analyzed materials, the occurrence of compressive stresses on the surface of the coatings has a beneficial effect on their mechanical properties, in particular on microhardness.

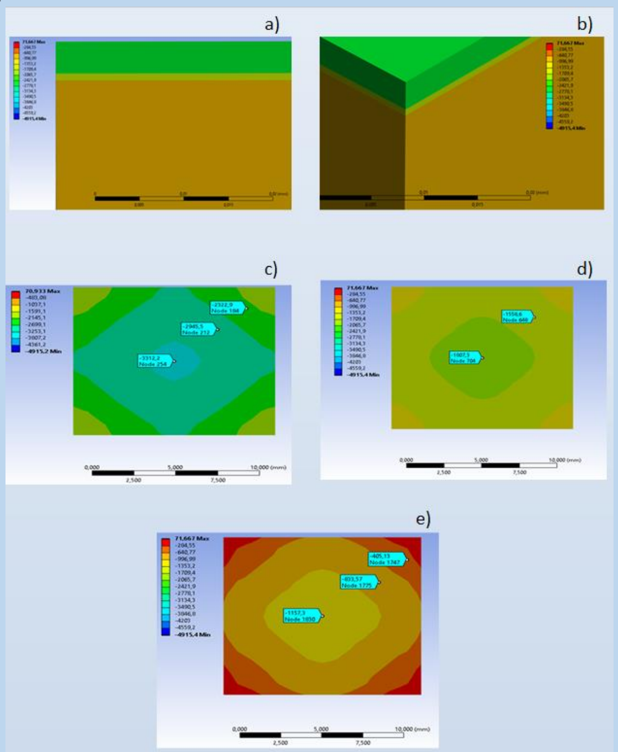

Fig. 5. Distribution of simulated compressive stresses in a sample with a TiN+(Ti,Al,Si)N coating on a CM substrate, with a visible boundary between the coatings and the substrate: a) 2D view, b) 3D view, c) in the outer TiN+ coating (Ti,Al,Si)N, d) at the interface between the (Ti,Al,Si)N coating and the TiN coating, e) at the interface between the TiN coating and the CM substrate.

Sumary

• It is assumed that the developed models based on numerical simulation of stresses and microhardness with the use of the finite element method will largely eliminate the need to conduct costly and time-consuming or even impossible experimental research in favor of computer simulation.

• The most important for this thesis was the comparison of experimentally obtained results of stress measurements of two-layer PVD coatings of the TiN+(Ti,Al,Si)N type, formed on cermets with the results obtained on the basis of the developed numerical model using the finite element method.

• In order for the coating applied on the tool to fulfill its task properly, it must be characterized by appropriate functional properties determined by numerous factors, among which the following should be mentioned: proper structure, chemical and phase composition, appropriate hardness and thickness, and above all, high adhesion to the substrate material.