The definition of the curve of stress-strain by indentation and scratch test

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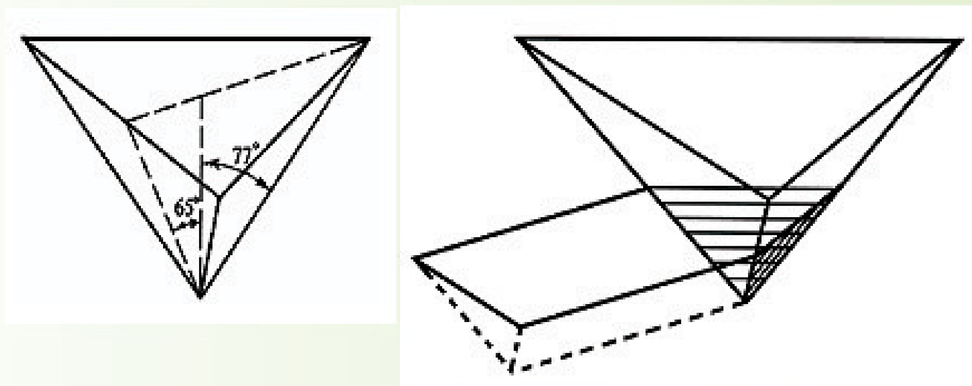
The mechanical characteristics of materials, e.g. the true stress - true strain relation, have been determined using the type compression or tensile test. Though in the microscale and mesoscale it is difficult to carry out this tests. Therefore, for this purpose it is used different methods basing on the results of indentation. In the works [1] was suggested various methods for determination of quantitative strength characteristics of materials (such as Young modulus, yield strength, hardness, coefficients in functional dependence of strain resistance). The object of work is to present the method for definition of the stress-strain curve of metals from indentation, scratch test and computational simulations. The method based on the results of indenter penetration in elastoplastic material and scratch test modeling by a finite element method.



Geometry of a indenter Berkovich showing the edge scratching directions

Experiment

Tests for the samples were performed on a Hysitron TriboIndenter TI 900, which is a high-resolution nanomechanical test instrument that performs nanoscale indents by applying a force to an indenter tip while measuring tip displacement into the sample. A pure cupper was used for experimental invistigation. A diamond indenter with Berkovich Geometry was used to perform the indentation experiments and the computational simulations.

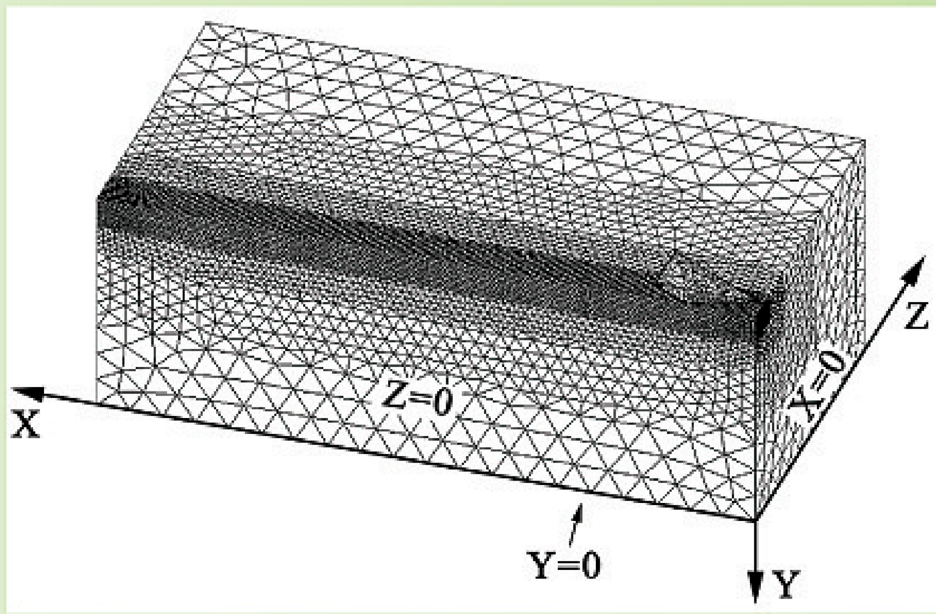
Computational simulation

Elastic-plastic scratch test was performed using the the ANSYS software package using the large strain feature with uniaxial stress-strain input data.

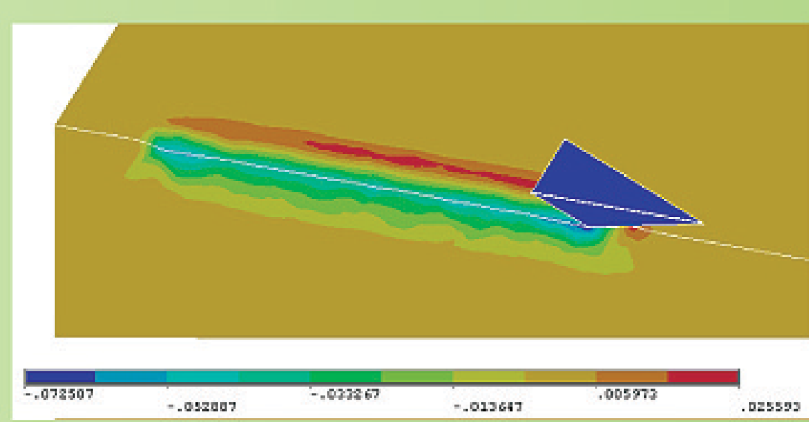
The specimen is rectangle specimen witch constrained both in horizontal and vertical directions. Due to the symmetry of the problem, the indenter are treated as one-half part of three-dimensional body and specimen as one-fourth part of three-dimensional body. The indenter and the specimen are shown in figure with the appropriate boundary conditions for the problem. The nodes on the side 1 can not move along the x-axis, the nodes on the side 2 cannot move along the z-axis and all the nodes on the bottom of the mesh are fixed. The friction coefficient μ between the indenter and the specimen was assumed to be 0,1.

<u>The indenter</u> - a linear elastic plastic isotropic material:
Young's modulus E = 1140 Gpa,
Poisson's ratio ν = 0,07.

<u>The material</u> - multilinear elasticplastic with isotropic hardening behavior,
$\sigma = E\varepsilon$, for $\varepsilon < \varepsilon_0$
$\sigma = a\varepsilon^b$, for $\varepsilon \geq \varepsilon_0$
σ - Mises`s yield load;
ε - total deformation with respect to Mises;
a - the work-hardening rate was varied from 200MPa to800MPa;
b - the work-hardening exponent was varied from 0,1 to 0,6.



The finite element mesh of the scratch test and boundary condition



The contours of Y displacement

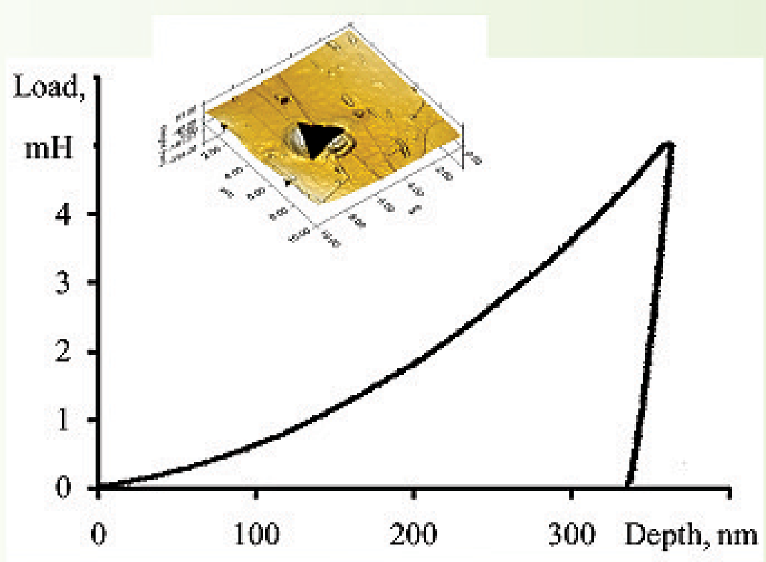
Result

Under modeling results it was obtained required volume of calculation data for set of *a* and *b* values. It was graphed the nomograms of penetration depth h_{ind} and scratch depth h_{scr} vs coefficient *a* when *b* was constant. The finding dependences were approximated power function, $h = ca^d$, where approximation factors c and d are resulted in table. Substituting experimental values penetration depth h_{ind} and scratch depth h_{scr} in the nomograms we receive value set a-b for indentation and scratch test. These value sets were described graphically. These dependences a-b for indentation and scratch test will be crossed in one point. It is a point will define desired values of coefficients a and b in the power law $\sigma = a\varepsilon^b$

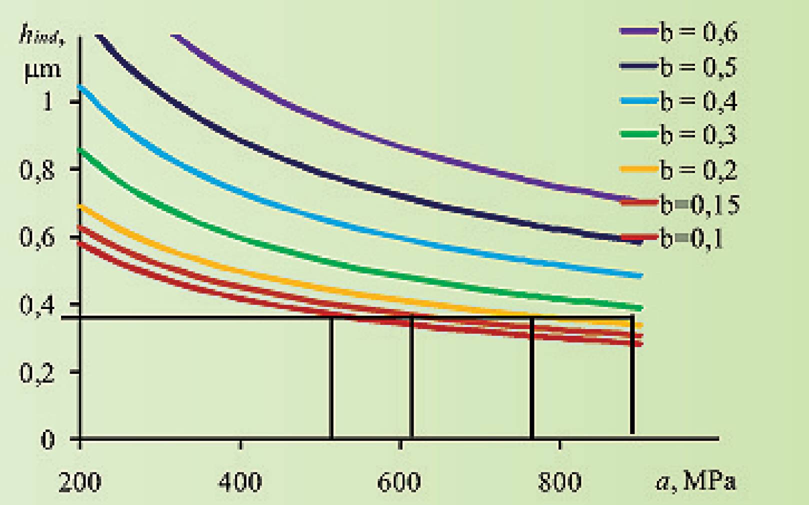
The approximation coefficients *c* and *d*

$$h = ca^d$$

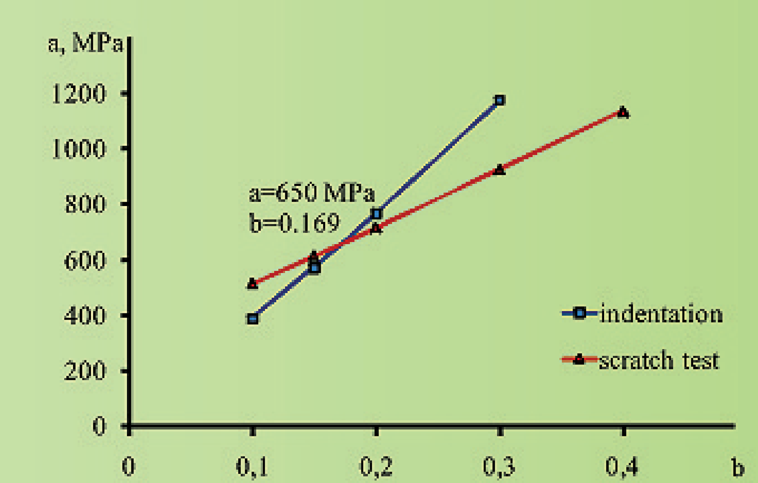
	indentation		scratch test	
b	*c*, MPa	*d*	*c*, MPa	*d*
0.1	7.0927	-0.473	5.1538	-0.441
0.15	7.9043	-0.478	6.1168	-0.458
0,2	8,4998	-0,474	9,8364	-0,512
0,3	13,441	-0,52	15,562	-0,563
0,4	15,606	-0,511	31,767	-0,657
0,5	19,344	-0,515	46,631	-0,687
0,6	23,582	-0,517	82,403	-0,749



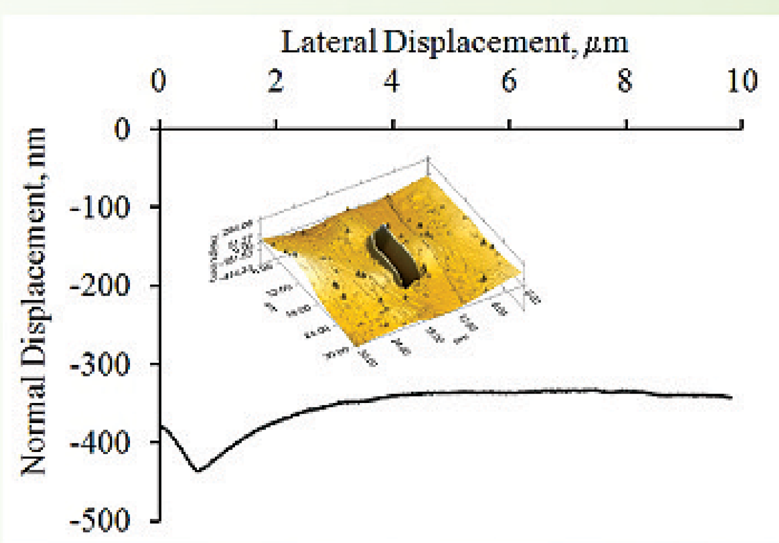
The diagram of indentation



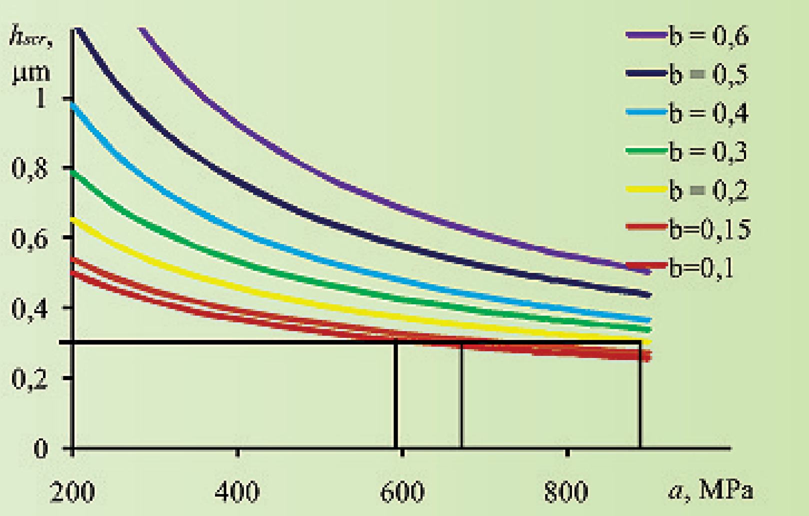
The nomogram of penetration depth h_{ind} vs coefficient *a* when *b*=const



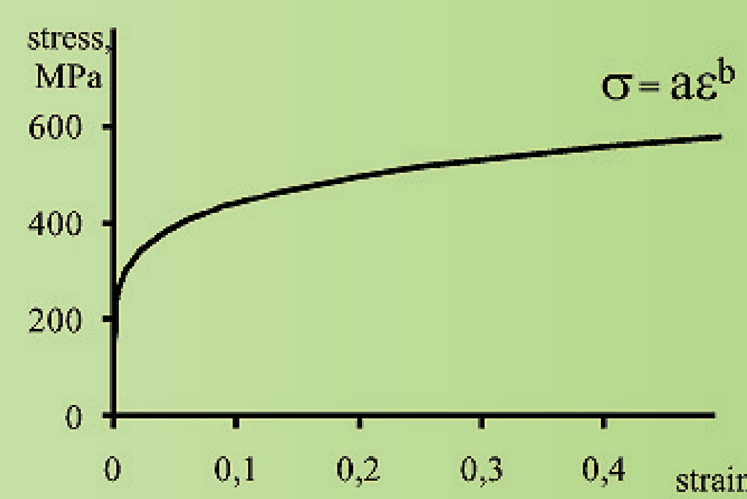
The determination scheme of coefficient a and b in the power law $\sigma = a\varepsilon^b$



The diagram of scratch test



The nomogram of scratch depth h_{scr} vs coefficient *a* when *b*=const



The restored curve stress-strain of copper determination scheme of coefficient a and b