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IMPROVEMENT OF EXPERIMENTAL –ANALYTICAL TECHNIQUE AIMED AT INVESTIGATION OF STRESSED-STRAINED STATE OF CYLINDRICAL SPECIMEN TOOTH FLANK WHILE AXISYMMETRIC SETTING

The paper considers the technique of experimental study of tooth flank deformation of cylindrical specimen while axisymmetric setting with available friction on faces. Various approaches to application and measurement of coordinate grid in the process of deformation are analyzed. It was established that application of photography method for measurement the dimensions of specimen tooth flank coordinate grid allows to reduce 2 times labour input and duration of experimental research, avoid intermediate discharges of specimen during step-by-step deformation.

Key words: *stressed-strained state, setting of cylindrical specimen, tooth flank, coordinate grid, logarithmic deformations.*

Problem set-up and analysis of the recent research

Object of investigation. Processes of complex deformation.

Subject of investigation. Deformation of tooth flank surface of cylindrical specimen while axisymmetric setting in conditions of barrel formation.

Aim of investigation. Improvement of experimental of experimental-analytical technique of stressed-strained state of tooth flank surface of cylindrical specimen while axisymmetric setting.

Task of investigation. 1. Improvement of the method of coordinate grid application on tooth of flank cylindrical specimen. 2. Study and comparison of various of coordinate grid dimensions determination while axisymmetric setting. 3. Elaboration of recommendations, concerning the improvement of experimental part of experimental-analytical technique of SSS study of tooth flink of cylindrical specimen while setting.

Actuality of the study. Axisymmetric setting of cylindrical specimen is widely spread technological operation and one of the main kinds of laboratory study, aimed at determination of basic technological properties of the materials. As it is known from [1 - 4], while setting of cylindrical specimen of metaloplastic materials, cracks are formed on tooth flank. The degree of setting, when cracks appear, depends on the intensity of barrel, formation of tooth flink. In its turn, the intensity of barrel formation is determined by friction conditions on specimen faces [5 – 10].

Main part

In accordance with experimental-analytical technique of SSS investigation of tooth flink of cylindrical specimen it is necessary to obtain the dependence between axial and circular deformations in the form of the function set by the table [6 – 10]

$$\varepsilon_z = f(\varepsilon_\phi). \qquad (1)$$

Experimental-analytical technique of SSS determination provides differentiation of the dependence (1), that stipulates conditions to the technique of deformation, in particular to the conditions of obtaining of experimental data.

Experimental investigation of axisysmetric setting of cylindrical specimen, made of steel 45 and allay BT9 was carried out in the laboratory of the Department of Strengths of Materials and Applied Mechanisms of Vinnytsia National Technical University.

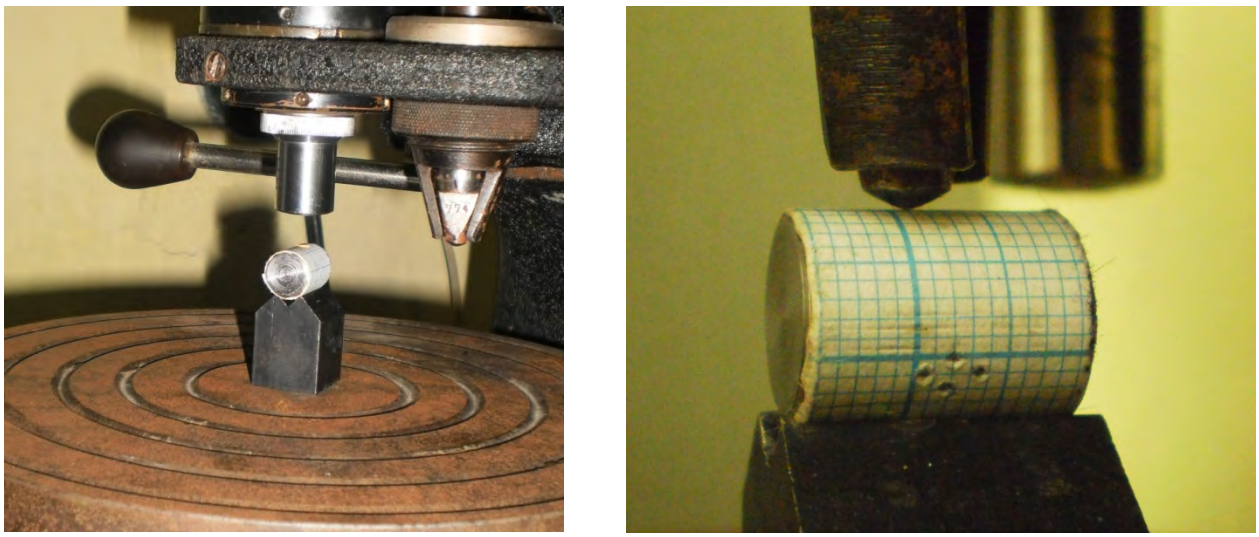
Cylindrical samples, made of the above mentioned materials were manufactured by turning on the lathe 1К62. As a result, samples, having such parameters, were obtained: BT9 –

($h = 16$ *mm.*, $d = 12h7$ *mm.*, roughness Ra 1,6), steel 45 – ($h = 14$ *mm.*, $d = 12h7$ *mm.*, roughness Ra 1,6).

In accordance with experimental-analytical technique of SSS investigation, in dangerous, from the point of vue of destruction, zone, i.e., on lateral surface of cylindrical sample, the coordinate grid must be applied [5 – 8]. To provide symmetrical location of the grid in the middle of lateral surface f the sample, the cross-section paper was struck, the middle point of lateral surface and peaks of the grid were marked. The next step was to apply the prints in indicates points on Vickers harness tester of ТП type (Fig. 1), as it is shown in Fig. 2. Forcing the indentor into the material was performed with the force of 20 kg.

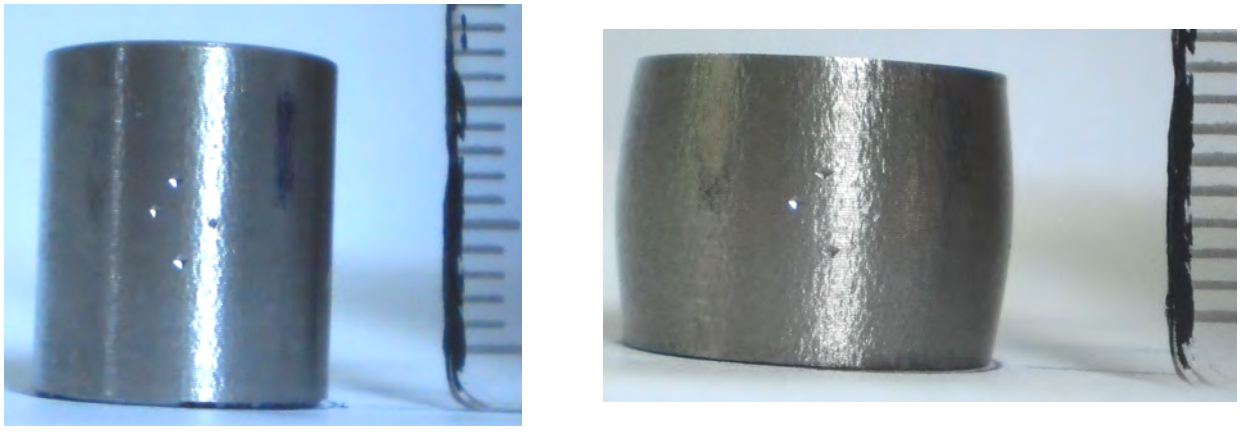
Fig. 1. Vickers hardness tester of ТП type

Coordinate grid was applied on each specimen in three planes with the step of 120°. To provide stationary while grid application the specimen was placed in the prism, located on working table of hardness tester, as it is shown in Fig. 2a. After application of the prints, the cross-section paper is eliminated from the surface of the specimen (Fig. 3a). The next step of experimental study of material deformation of specimen lateral surface is measurement of vertical and horizontal dimensions of the obtained coordinate grid. For this purpose toolmaker's microscope ММИ-2 was used (Fig. 4).



a) b)

Fig. 2. Application of the grid on lateral surface of cylindrical specimen: a) placement of the specimen on working table of the hardness tester; б) forcing of the indenter in the material of the specimen



а) б)

Fig. 3. Photograph of the specimen made of the allay BT 9: a) before axisymmetric setting; б) after loading 21 t.

The prepared specimen with applied and measured coordinate grid further were set on hydraulic press ПММ-125 (Fig. 5) using corresponding tool (Fig. 6). After each step the specimen was unloaded and changed dimensions were measured by means of toolmakers microscope ММИ-2. At the same time the application of photography method for measurement of specimen dimensions and its coordinate grid was investigated. The essence of the method is the following: the specimen is photographed using scale rule, that can be placed both in the plane of coordinate grid and in the plane of specimen axis. The obtained photographs are processed in CAD system Compas, magnifying the image several times. Using the photography method allowed to reduce twice labour input and duration of the experiment, as well as eliminate intermediate unloading by investigated specimen at step-wise setting.

a) b)

Fig. 4. Microscope ММИ-2 type (a) та and measurement of the coordinate grid dimensions(b)

Fig. 5. General view of hydraulic pressПММ-125

Fig. 6. Fixture of axisymmetric setting on hydraulic press ПММ-125

Deformation value of the specimen, made of alloy BT9 at each stage was set by increasing the applied load. The results of measurements of the grid in three planes after each step of loading by means of microscope ММИ-2 and photography method are shown in Tables 1 and 2 correspondingly. The specimen was destroyed, when load value reached 21,5 t. (Fig. 7).

Table 1

Values of the dimensions of coordinate grid of the specimen, made of alloy BT9, measured by means of microscope ММИ-2

Load, t	First grid		Second grid		Third grid	
	Horizontal, mm	Vertical, mm	Horizontal, mm	Vertical, mm	Horizontal, mm	Vertical, mm
0	1,885	2,145	1,19	2,84	2,139	2,99
21	2,61	2,095	1,28	2,258	2,341	2,775
21,5	Specimen destruction					

Table 2

Values of the dimensions of coordinate grid of the specimen, made of alloy BT9, measured by means of photography method

Load, t	First grid		Second grid		Third grid	
	Horizontal, mm	Vertical, mm	Horizontal, mm		Horizontal, mm	Vertical, mm
0	1,8657	2,0088	1,184	2,7411	2,0485	2,9849
21	2,5987	1,9525	1,2708	2,0882	2,3074	2,637
21,5	Specimen destruction					

Cylindrical specimen, made of steel 45 was deformed step by step, loading step being 5 t. The results of measurements of coordinate grid after each step of deformation by means of above-mentioned methods are presented in Table 3 and 4.

Deformation of the specimen, made of steel 45 was carried out to the load of 31.5 t, the cylindrical specimen obtained barrel form and was not destroyed (Fig. 8).

Analysis of the results of the investigation aimed at determination of coordinate grid dimemsions of the speciment, carried out according to measurement techniques, by means of microscope ММИ-2 and photography allowed to determine, that the measurement error of both methosd is within the same limits.

Fig. 7. Rupture of the specimen, mode of alloy BT9 while axisymmetric setting

Table 3

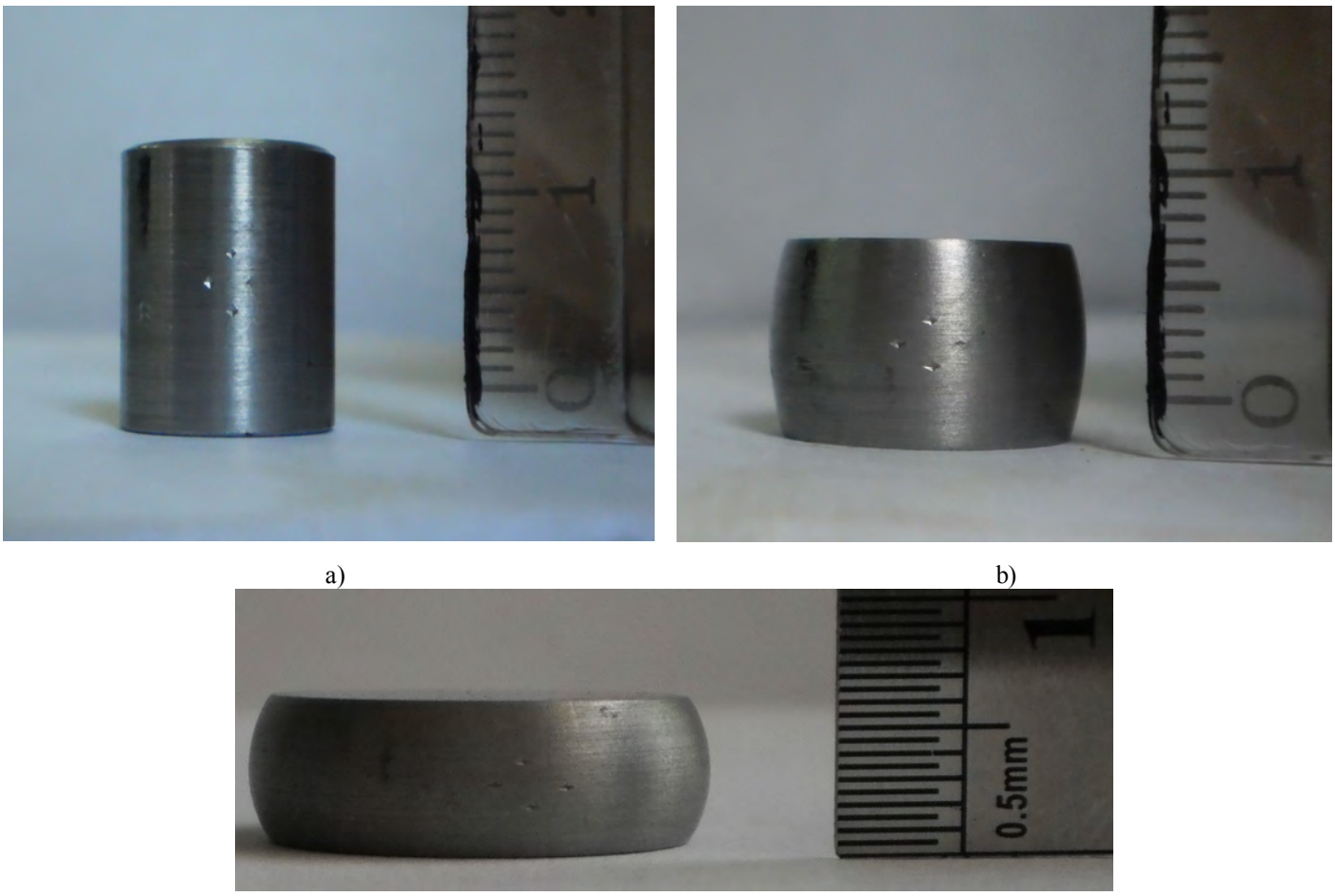
Dimensions values of coordinate grid of steel 45 specimen, measured by microscope ММИ-2

Load, t	First grid		Second grid		Third grid	
	Horizontal, mm	Vertical, mm	Horizontal, mm		Horizontal, mm	Vertical, mm
0	2,145	1,85	1,742	2,84	1,8025	2,735
5,3	2,56	2,99	1,69	3,115	1,792	2,77
10	2,215	2,82	1,695	2,95	1,769	2,642
15	2,505	2,295	2,03	2,405	2,015	2,142
20	2,82	2,002	2,273	2,11	2,375	1,814
25,1	3,086	1,827	2,44	1,847	2,578	1,707
30	3,32	1,664	2,605	1,715	2,762	1,55
35,1	3,555	1,725	2,748	1,725	2,995	1,01

Table 4

Dimensions values of coordinate grid of steel 45 specimen, measured by photography method

Load, t	First grid		Second grid		Third grid	
	Horizontal, mm	Vertical, mm	Horizontal, mm		Horizontal, mm	Vertical, mm
0	2,0847	2,9396	1,5004	3,183	1,532	2,758
5,3	2,0349	2,9231	1,6423	3,0225	1,6359	2,7078
10	2,1562	2,7824	1,7122	2,9717	1,7817	2,6011
15	2,4891	2,327	1,9458	2,3997	1,9988	2,0799
20	2,7216	2,014	2,1826	2,1209	2,251	1,8405
25,1	3,1176	1,943	2,4276	1,9113	2,4689	1,7041
30	3,3056	1,7772	2,6238	1,844	2,7224	1,6271
35,1	3,4551	1,4698	2,6738	1,575	2,9003	0,9826



a) b)

c)

Fig. 8. Cylindrical specimen, mode of steel 45: a)before axisymmetric setting; b) after loading 20 t.; c) after loading 31,5 t.

Using the obtained dimensions of the coordinate grid of lateral surface of cylindrical specimen, we define the value of axial ε_z and circumferential ε_φ of logarithmic deformations:

$$\varepsilon_z = \ln\left(\frac{b}{b_0}\right);\ \varepsilon_\phi = \ln\left(\frac{a}{a_0}\right), \tag{2}$$

where a, a_0, b, b_0 – are current and initial horizontal an vertical dimensions of coordinate grid. They are initial data of analytical part of experimental-analytical technique of SSS investigation and ultimate strains at axisymmetric setting[5 – 10].

Conclusions

1. The improved technique of coordinate grid application allows to apply symmetrically marks relatively central area of lateral surface of cylindrical specimen.

2. While experimental research of lateral surface of cylindrical specimen material deformation measurement of coordinate grid dimensions is better to perform, using photograph method. It allows to accelerate the experimental research, partially automate the procedure of coordinate grid measurement and eliminate the influence of numerous unloading of the specimen while step-by-step axisymmetric setting.

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