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The Peculiarities of the Influence of the Finite Sizes of a Detail on the Distribution of the Surface Layer Micro-hardness

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It was found that under wave deformation hardening the state of a generated wave, depending on the geometry of the workpieces, has a significant impact on the surface layer micro-hardness distribution.

Keywords: Deformation wave, Hardening, Geometric dimensions, Wave processes, Static-pulse treatment.

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1. INTRODUCTION

In carrying out engineering calculations the dimensions of the investigated models are often neglected. On the one hand, it can greatly simplify the calculation of the plane model, but on the other hand, exclude the consideration of the effect of the sample geometric dimensions on the process under study. In the study of strike systems, which are based on wave processes, we should not exclude the influence of the finite size of the samples on the process of hardening. This is due to the fact that the nature of elasto-plastic deformation has got its peculiarities, since hardening is performed by the transmission of energy in the form of a deformation wave, which is converted on all borders with variable acoustic impedance, including borders, which are the final dimensions of the test sample.

Hardening wave deformation was investigated in the past, but in those studies the finite size of the sample was not taken into account [1, 3].

The aim of this work is to identify patterns of influence of the finite size of the material on the distribution of micro-hardness of the surface layer under its wave deformation hardening.

2. DESCRIPTION OF THE OBJECT AND RESEARCH METHODS

For studies, samples made of steel 45 with various ratios of geometrical dimensions: length, width, thickness were taken (Table 1).

These samples were reinforced by wave deformation on a static pulse processing installation (plant) (SPP) [1]. The peculiarity of the method consists of a periodic pulsed impact of the striker on the load-bearing environment through a statically loaded waveguide. Preliminary waveguide static loading by a single-contact indenter in the form of aroller at the end of the rod does not allow it to go out of contact with the load bearing face after the strike, ensuring the recuperation of deformation reflected waves. With the SPP the use of a load by controlled shock pulses provides more opportunities for the formation of a hardened surface layer with a great depth (up to 6-8 mm), high degree (up to 6500 MPa) and the required uniformity of hardening (with the possibility of receiving heterogeneous structure that increases durability) [3-4]. To eliminate the influence of the SPP parameters on the investigated process a samples hardening process was carried out with one and the same treatment: the impact energy of 25 J; impact frequency of 23.3 Hz; prints overlap factor $K = 0.4$; a tool – a cylindrical roller with the width of 7 mm and a diameter of 10 mm.

As a result, the deformation wave effects hardness and changes the structure of the material. The changes in surface layer micro-hardness revealed the influence of the finite size of the material on the process of hardening.

To research micro-hardness, hardened samples were cut in the longitudinal feed direction (cross section A-A) (Fig. 1).

In order to assess whether the pattern of micro-hardness distribution changes throughout the investigated ZY plane in the longitudinal and transverse direction with a pitch of 0.3 mm, several samples were completely measured. The result of the measurements proved that the pattern of micro-hardness propagation repeated across the sample plane. Based on these data, it was decided not to carry out research across the whole ZY plane, but only on a fragment of the surface of 15 mm wide, located in the center of the sample (Fig. 1).

In order to establish the impact of technological heredity on micro-hardness distribution diagrams, several samples were measured before hardening (Fig. 2a, b).

Table 1 – Geometrical dimensions of samples, mm

Length	Width	Thickness	Length	Width	Thickness	Length	Width	Thickness
50	20	10	100	20	10	150	20	10
50	40	10	100	40	10	150	40	10
50	40	20	100	40	20	150	40	20

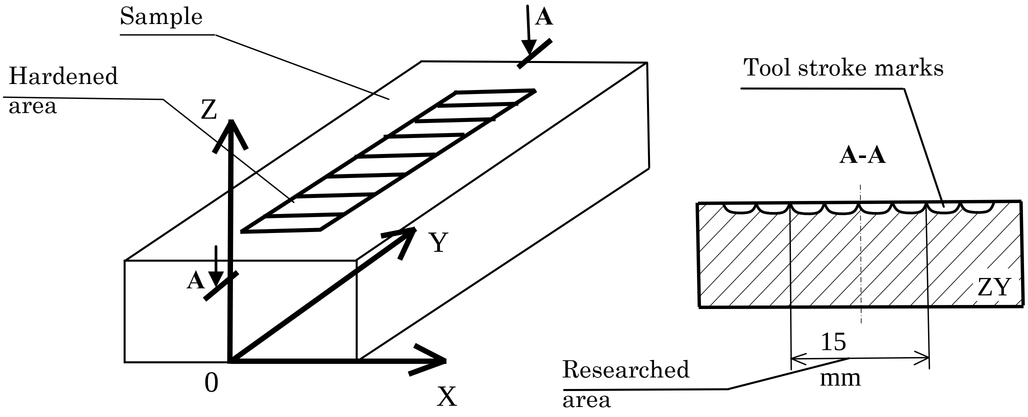
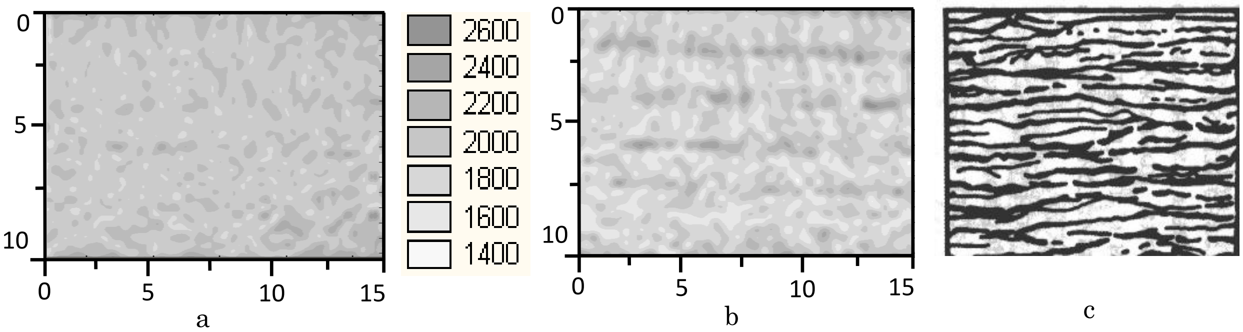


Fig. 1 – Investigated sample scheme



a b c

Fig. 2 – Diagrams of micro-hardness distribution in the unreinforced samples (a and b); metal macrostructure after pressure treatment (c) [2]

The measurement results showed that the areas with a hardness $N_\mu = 1800$ MPa ($N_\mu = 1728$-1761 MPa) prevail. These values should be considered the initial hardness. Areas of high hardness $H_\mu = 2000$ MPa are located mainly on the edges (Fig. 2a, б), as well as randomly – fragmentarily across the surface of the samples. In Fig. 2b areas of increased hardness relative to the initial 200 MPa, are arranged in the form of several horizontal bars (macrostructures fiber) extending through the entire cross section of the sample under consideration. The appearance of these areas is a result of technological heredity from previous operations at the production stage of the starting material samples. An example of a similar metal macrostructure obtained after pressure treatment is presented in [2], Fig. 2b.

3. DESCRIPTION AND ANALYSIS OF RESULTS

The diagrams obtained due to the measurements of the distribution of micro-hardness of the reinforced samples (Table 1) are shown in Fig. 3. The analysis showed that the diagrams are of a different nature of micro-hardness distribution despite the fact that they were reinforced with the same SPP mode. This indicates that the final dimensions of the reinforced material influence the process of deformation wave propagation.

Comparing the diagrams in Fig. 2 and 3, it can be concluded that technological heredity has no noticeable effect on micro-hardness distribution at hardening.

For the samples with different geometric dimensions, but the same volume (for example, the volume of the sample $50 \times 40 \times 20$ and $100 \times 40 \times 10$ is 40000 mm^3), different pictures of micro-hardness distribution were set (Fig. 3). This fact is another confirmation of the significant influence of the material geometric dimensions on micro-hardness distribution at wave deformation hardening.

The comparative analysis of the diagrams of micro-hardness distribution in the surface layer allowed us to establish the following patterns of material finite size influence on the surface layer micro-hardness distribution when the layer is hardened by a deformation wave of deformation hardening. Thus, when the length was doubled (up to 100 mm), the samples $100 \times 40 \times 20$; $100 \times 40 \times 10$; $100 \times 20 \times 10$ showed a decrease in maximum attainable hardness by 7.2 %, 7.1 % and 5.9 % respectively (Fig. 3). In the samples $100 \times 40 \times 20$ and $100 \times 20 \times 10$ there was a through-hardening, minimum attainable hardness was 2400 MPa. When the length was increased (up to 100 mm) the depth of hardening of the sample $100 \times 40 \times 10$, as compared with $50 \times 40 \times 10$, decreased by 3.2 times.

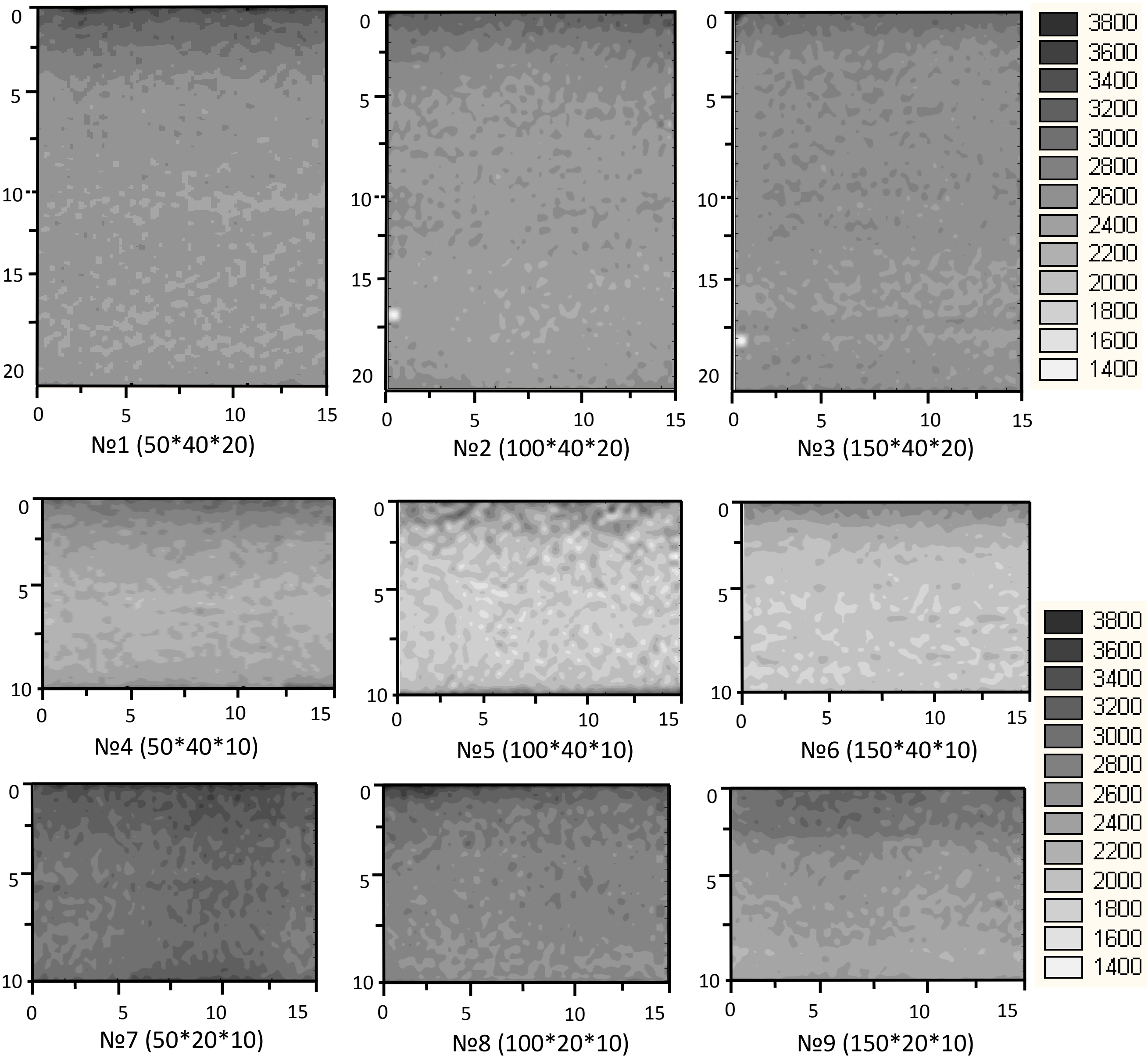
After tripling the length (up to 150 mm) of the samples $150 \times 40 \times 20$; $150 \times 40 \times 10$; $150 \times 20 \times 10$ maximum attainable hardness decreased by 7.2 %, 7.1 % and 5.9 % respectively and amounted to 3000 MPa, 2600 MPa and 3200 MPa respectively (Fig. 3). In the samples of $150 \times 40 \times 20$ and $150 \times 20 \times 10$ there is a through-hardening, the minimum attainable hardness was almost unchanged and amounted to 2400 MPa and

2200 MPa respectively. When the length was increased to up to 150 mm, the depth of hardening of the sample 150 × 40 × 10, as compared with the sample 50 × 40 × 10, decreased by 3.4 times.

After doubling the thickness (up to 20 mm) of the examined samples 50 × 40 × 20; 100 × 40 × 20; 150 × 40 × 20, maximum hardness increased by 12.5 %, 13.3 % and 13.3 % respectively. Also, with increase of thickness of the samples 50 × 40 × 20; 100 × 40 × 20; 150 × 40 × 20, the appearance of continuous surface layer hardening was noted, the lowest attainable hardness was 2200 MPa, 2400 MPa and 2400 MPa respectively.

After a double increase (up to 40 mm) of the width of the samples 50 × 40 × 10; 100 × 40 × 10; 150 × 40 × 10, maximum achievable hardness decreased by 17.6 %, 18.7 % and 18.7 % respectively and constituted 2800 MPa, 2600 MPa and 2600 MPa respectively. Increasing the width to 40 mm in the samples 50 × 40 × 10; 100 × 40 × 10; 150 × 40 × 10 also led to a decrease in the depth of hardening by 52 %, 85 % and 86 % respectively.

The above mentioned features of the hardened surface layer formation by wave deformation due to the change of its geometric parameters are of a complex nature, the detailed study of which may be important in practical terms.



№1 (50*40*20) №2 (100*40*20) №3 (150*40*20)

№4 (50*40*10) №5 (100*40*10) №6 (150*40*10)

№7 (50*20*10) №8 (100*20*10) №9 (150*20*10)

Fig. 3 – Diagrams of micro-hardness distribution in the investigated samples

4. CONCLUSIONS

– it was found that the geometrical dimensions of the processed material dramatically affect the wave deformation hardening process, as at equal volumes of the hardened samples and different processing conditions different diagrams of the surface layer micro-hardness distribution were observed;

– it was found that at wave deformation hardening the increase of the samples length from 50 to 100 mm leads to a reduction in hardness by 6.7 % on average, and the depth of hardening by 3.2 times (only for the sample 100 × 40 × 10);

– it was found that at wave deformation hardening the increase of the samples length from 50 to 150 mm on average leads to a reduction in their hardness by 6,7 %, and the depth of hardening by 3,4 times (only for the sample150 × 40 × 10);

– it was found that at wave deformation hardening the increase of the samples thickness from 10 to 20 mm leads to an increase in their hardness by 13 % on average, and the depth of hardening by 10,3 times; – it was found that at wave deformation hardening the increase of the samples width from 20 to 40 mm leads to an average reduction in hardening by 18,3 %, and the depth of hardening by 5,2 times.

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