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The influence of technological parameters on physical and mechanical properties of surfaces

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Annotation. In this study, we examined how the parameters of external mechanical impact by microdeforming the surface influence the energy state of a solid body at the interphase boundary. We studied the dependence of the surface energy on microdeformation modes with different values of the line interval and the elastic recovery of multicomponent iron-based materials. The measurements were performed on experimental samples of C20, C45, X10Cr13. The results of the study can be used to ensure the required performance properties of products.

1. Introduction

To concur with the never-ceasing growth of technical requirements to engineering products and instrument-making, it becomes necessary to improve the existing technologies and to develop new ones. Several studies [1-8] show a stable relationship between the performance properties of products and the energy parameters of surfaces.

Examination of the features of energy parameters [9-13] of a substrate of structural materials with metallic properties helps get an insight into the change in the properties of near-surface areas. It is known that the energy state of surfaces of a solid body at the phase boundary is determined, among other things, by the structure and state of the crystal lattice [14-16]. Therefore, it is important to know how to form a certain level of energy state on a surface by means of external mechanical impact. The aim of this study was to examine the effect of the parameters of external impact by microdeforming the surface on the surface energy (SE) of multicomponent iron-based materials.

2. Materials and methods

To conduct an experimental study of the change in SE of materials when microdeforming line-by-line, impact on the surface of the samples was simulated. The materials of the experimental samples are C20, C45, and X10Cr13. The material of the tool (cutting edge) is GC1040. The blunting radius of the cutting edge of the tool $\rho = 0.02$ mm. Microdeforming was performed on a vertical milling machining centre with a MiniMill 450 CNC machine. In the process, the values of the surface energy were determined by the method described in [17]. The hardness of the material under study was determined on the Brinell scale using a hardness meter.

The influence of microdeformation modes on the surface energy at different values of elastic recovery h_y was examined with regard to:

- materials of rigid structures – the h_y value less than 1 μm ;



– materials of the structures prone to elastic recovery after shaping by removing part of the surface
 – $h_y \approx 2 \mu\text{m}$ and $h_y \approx 4 \mu\text{m}$.

The assessment was performed according to the methods described in [18].

3. Results and discussion

To determine the effect of the line interval (longitudinal tool feeding) on the SE change, its f_z value was decreased and increased by 30% during microdeformation with the help of a milling tool. The graph of SE dependence on the line interval during microdeformation after removing part of the metal at depths $h = 500 \mu\text{m}$, $h = 300 \mu\text{m}$ and $h = 100 \mu\text{m}$ is shown in Fig. 1.

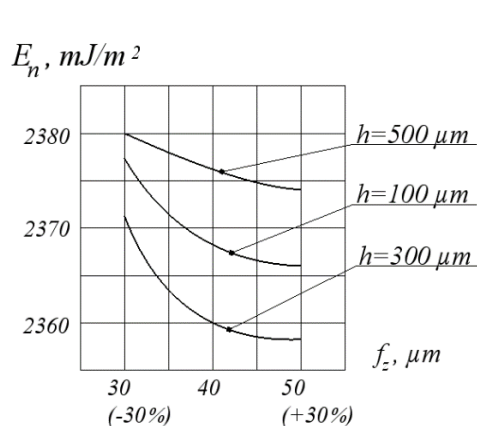


Figure 1. Dependence of surface energy on the line interval

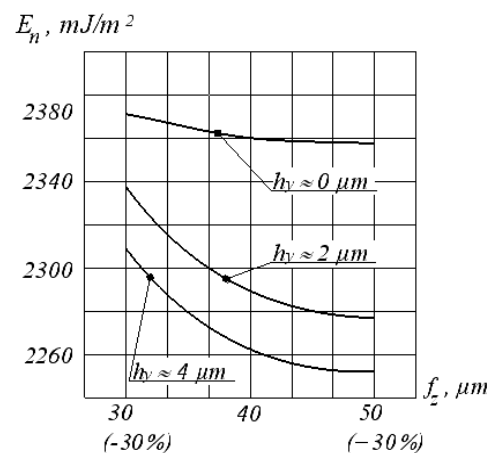


Figure 2. Dependence of the surface energy on line interval f_z and the depth of line-by-line microdeformation h_y after preliminary shaping of the surface by removing material to depth $h = 300 \mu\text{m}$

Analysing the graphs, we can conclude that as line interval f_z is increased during microdeformation, the SE value decreases. The lowest value of SE is accumulated during microdeformation after removing a layer of depth $h = 300 \mu\text{m}$, and the highest value of SE – after removing material to the depth of $h = 500 \mu\text{m}$.

Then, the influence of microdeformation parameters on the SE value was determined. The surface energy resulting from the change in the value of elastic recovery after shaping ($h_y \approx 0 \mu\text{m}$, $h_y \approx 2 \mu\text{m}$ and $h_y \approx 4 \mu\text{m}$) was measured. The results of the experiments with microdeformation of the surface after removing material to depth $h=300 \mu\text{m}$ are shown in Fig. 2.

The analysis of the results revealed that as the depth of microdeformation h_y increases, the value of surface energy decreases. This is due to the smoothing of the microrelief vertices of the surface accompanied by unloading of the energy concentrator zones.

The effect of microdeformation parameters on the SE of other materials was studied in a similar way. The material of the samples is C20. The surface energy resulting from the change in the value of elastic recovery after shaping by cutting ($h_y \approx 0 \mu\text{m}$, $h_y \approx 2 \mu\text{m}$ and $h_y \approx 4 \mu\text{m}$) was measured. The results of the experiments with microdeformation of the surface after removing material to depth $h=300 \mu\text{m}$ are shown in Fig. 3.

The analysis of the results revealed that as the depth of microdeformation h_y (due to the impact of elastic recovery) increases, the SE value decreases.

When examining samples from X10Cr13, the surface energy resulting from the change in the value of elastic recovery after shaping by removing a layer of material ($h_y \approx 0 \mu\text{m}$, $h_y \approx 2 \mu\text{m}$ and $h_y \approx 4 \mu\text{m}$) was measured. The results of the experiments with microdeformation of the surface after cutting to depth $h=300 \mu\text{m}$ are shown in Fig. 4.

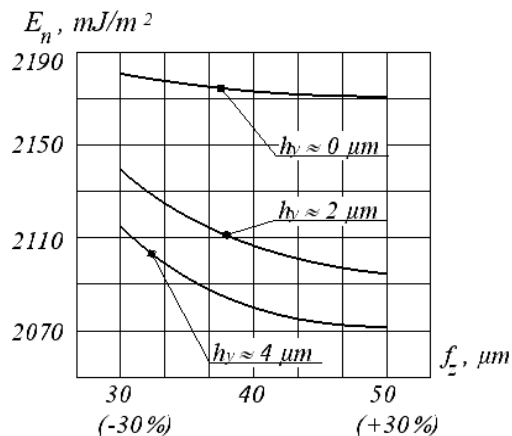


Figure 3. Dependence of the surface energy on line interval f_z and the depth of microdeformation h_y after shaping by removing material to depth $h = 300 \mu\text{m}$ (C20)

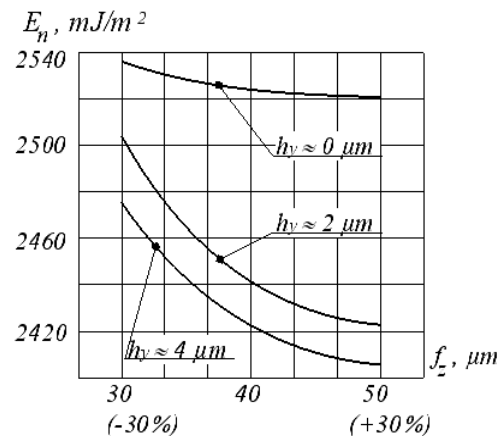


Figure 4. Dependence of the surface energy on line interval f_z and the depth of microdeformation h_y after shaping by removing material to depth $h = 300 \mu\text{m}$ (X10Cr13)

The analysis of the results revealed that as the depth of microdeformation h_y increases, the value of surface energy decreases.

4. Conclusions

For materials C20, C45 and steel X10Cr13, the SE measurement results revealed:

- in order to obtain the maximum level of SE, after removing a layer of material to depth $h = 300 \mu\text{m}$, microdeformation should be carried out;
- as line interval f_z increases during microdeformation of materials, the SE value decreases;
- as the depth of microdeformation increases, the value of surface energy decreases.

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