International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 2 (2018) pp. 1381-1384
© Research India Publications. http://www.ripublication.com

Generation of Energy State of Iron-Based Construction Material Surfaces

[1,a]Mousokhranov M.V., [1,b]Kalmykov V.V., [1]Gorbunov A.K., [1]Sapegina O.P. and [2]Sorokin S.P.

[1] Kaluga Branch of Federal State Budgetary Educational Institution of Higher Education "Moscow State Technical University named after N.E. Bauman (National Research University)," 2, Bazhenova Street, Kaluga 248600, Russia.

[2] Federal State Budgetary Educational Institution of Higher Education "Moscow State Technical University named after N.E. Bauman (National Research University)," 5, Baumanskaya 2-ya Street, Moscow 105005, Russia.

[a]Orcid: 0000-0002- 9870-8343 & Researcher ID: O-4261- 2016, [b]Orcid: 0000-0002- 8487-755X & Researcher ID: J-8755- 2016

Abstract

The work is carried out with a view to establish a mechanism determining the changes of surface energy value according to the modes of technological influence at edge cutting machining of construction materials. This variability leads to irregularity of product performance characteristics, such as wear resistance and durability.

Surface energy of parts is taken into account while performing various technological operations such as welding, soldering, gluing, application protective coating, etc., during production, operation and repair. Meanwhile, this problem is very complicated, as the same materials are remarked to have variable surface energy values. The dependence between technological parameters during production of parts and their surface energy value is established.

As a physical characteristic the electronic work function was suggested, allowing to estimate the energy state of iron-based construction materials. Relationship between the intensity of abrasive machining of construction steels and the surface electronic work function is determined. Relationship between stressed and energetic state of metal surfaces is shown.

The materials of the article may be useful for technology development providing high operational characteristics of items made with construction materials.

Keywords: construction materials, operational properties, surface layer, contact potential difference, electronic work function.

INTRODUCTION

Numerous studies of energy potential of bodies in the condensed state suggest that the electronic work function (EWF) is the most capacious physical characteristic for determining the surface energy of metals. EWF level is influenced by structural transformations in the surface layer: distortions and destructions of crystalline lattices, alloying process, etc. At technological generation of part surface made with iron-based construction materials electronic density redistribution occurs. Based on the works [1–4], it is possible to accept that energy transfer from one element to another is constant. Controlling the values of energy levels is quite possible by relevant technical methods with which these levels are brought to the desired value.

EWF value can be considered as an indicator of surface energy of a condensed system (CS). Since, above all, it is understood as technological impact the modification of machining modes, so it is practically feasible to slightly change the feed value or the cutting speed, and in some cases – the cutting depth.

The experiment does not involve determination of surface energy in its final form, but obtaining the values of certain energy constants, which would allow to determine the value of the surface layer energy.

EWF is a relatively sensitive characteristic of surface states, and, in the same way as the value of surface energy, it is different for various crystal facets. Due to the great complexity of the considered phenomena there is no any strict theoretical justification by calculations yet.

The work objective is to study the physical-mechanical properties of iron-based materials, of steel C45, 41Cr4, Fe37-3FN.

MATERIALS AND METHODS

Physical-mechanical properties of the surface layer of equipment parts change under the influence of technological medium as a result of impact of strength and thermal factors. While machining with abrasive tool the main influence on the surface state is performed by strength and thermal factors. The result of such impact is the structure destruction, displacement of crystals and turns, as well as surface hardening [5-6]. With that, in the part surface layer it is possible to distinguish the following zones:

- strong deformation zone, characterized by considerable distortions of the crystalline lattice, crushing of crystals, increase of micro-hardness;
- zone characterized by stretching crystals along the machining, by overlapping of ones by the others, by reducing micro-hardness (compared to the first zone);
- zone of transition from the zone subjected to technological influence and the one of the main metal.

Figure 1 conceptualizes interaction of the abrasive cutting wedge with the iron-based construction material. By performing the main cutting movement Dr, the grinding wheel moves along a linear trajectory, providing cutting depth h, to which it was adjusted prior to the cutting process. However, it

© Research India Publications. http://www.ripublication.com

is known that the machined surface, after tool removal due to elastic recovery rises slightly and takes a new position at the distance h_y from the previous one [5].

In the light of the foregoing, the interaction of abrasive grain as an element, such as abrasive wheel, abrasive brick, or abrasive grain in powder form does not possess any particularities.

The diagram analysis according to Fig. 1 leads to the most important conclusions. Restoring by the value b1 occurs after tool removal, when, seemingly, such forces cease to impact the machined material. In fact, recovery takes place under the influence of energy of the surface layer of the CS material. Moreover, h_y values are very closely related to the machining method, as well as to the technological process modes. The last fact directly points out that the layer energy state can be modified by selection of relevant machining modes.

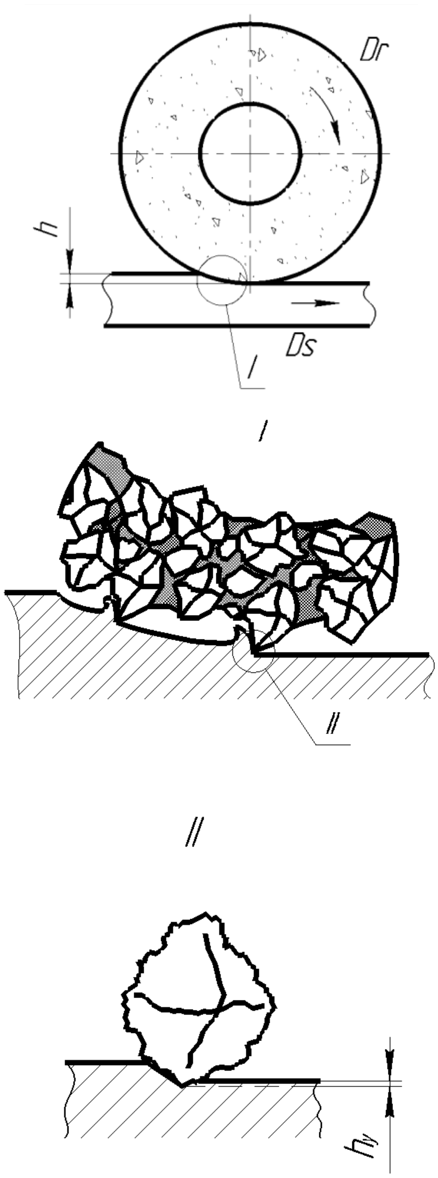

Figure 1. Interaction of the abrasive cutting wedge while grinding

The base of mechanical machining and operation is elastic-plastic deformation of the surface layer, resulting in heating and cooling, structural phase transformations, as well as energy absorption. The absorbed energy is accumulated in the surface layer and has a significant impact on its operational characteristics. Certain sources point out the dependence of physical-mechanical properties of the material on the CS surface energy [10–12].

In particular, while grinding when the front angle of abrasive grain is negative, the tensile stresses are created. This is due to the prevailing influence of temperature in the cutting zone and to uneven cooling, which leads to stretching of the quickly solidifying, under the influence of the coolant, surface layer from the side of internal layers, i.e., to creation in it of tensile residual stresses [2].

In this paper, for reaching the set objective the task was to assess the EWF modification depending on the abrasive machining modes [13-18]. As an object of study samples of construction steels C45, 41Cr4, Fe37-3FN were selected. Each material was subjected to mechanical machining at the flat grinding machine in the range of feeds *f* from 0.029 to 0.051 mm/course. After machining the electronic work function was determined with the help of the pilot unit.

STUDY RESULTS

The experiment results are given in Table 1.

Table 1: Experimental values of the electronic work function,

f, мм/rev	C45	41Cr4	Fe37-3FN
0,029	6,90388E-19	6,905E-19	6,9334E-19
0,036	6,91256E-19	6,9098E-19	6,93464E-19
0,041	6,9168E-19	6,91744E-19	6,93748E-19
0,051	6,92324E-19	6,92404E-19	6,93896E-19

The EWF values were calculated according to the dependence [7-9]:

$$\varphi_{Me} = \varphi_e - e \cdot V_c \, .$$

where φ_e is the electronic work function; e is the electron charge; φ_{Me} is the electronic work function of the studied sample; V_c is the contact potential difference of the studied sample.

EWF dependence on the value of longitudinal feed at grinding of iron-based construction materials is represented in Fig. 2.

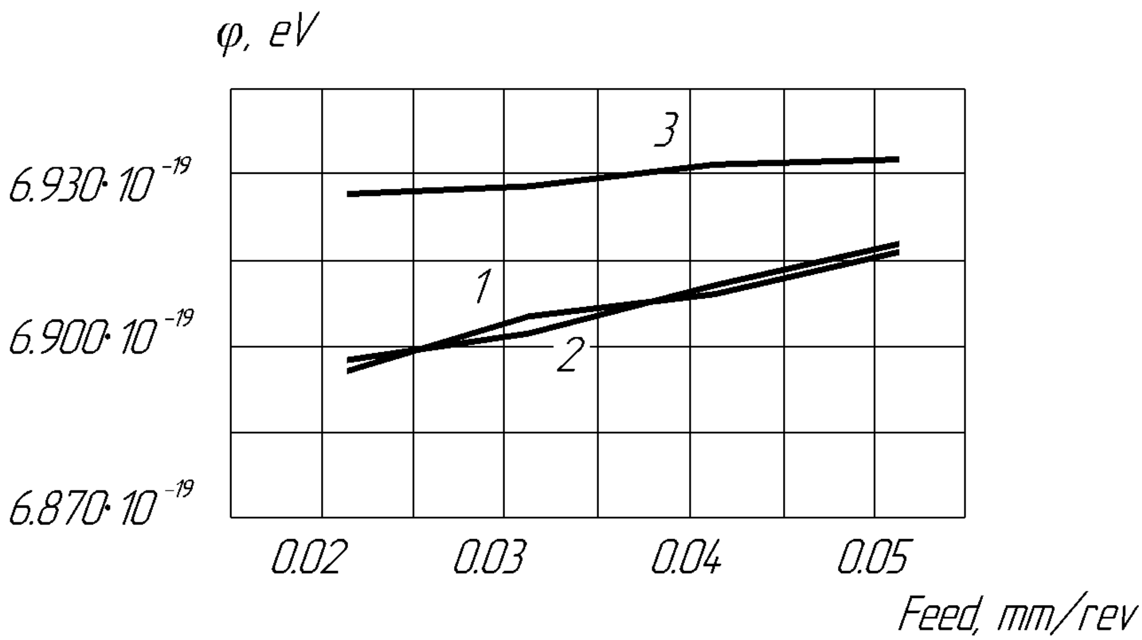

Figure 2. Dependence diagram of the electron work function on the feed value at grinding.

From the diagram it can be seen that by increasing the longitudinal feed on the course at grinding, the EWF value of the studied samples made with steel C45, 41Cr4, Fe37-3FN increases.

SUMMARY AND CONCLUSIONS

Analysis of the experiment results shows for all three construction materials the same pattern of EWF increase with increasing longitudinal feed at surface grinding. A characteristic feature of the grinding operation is the increased values (approximately 1,200 ^{0}C) of the temperature in the cutting zone. As grinding is accompanied by intensive feeding of the coolant-lubricant, the surface is cooled faster. Because of the difference of cooling speed of the outer and inner part of the material, tensile residual stresses [9] are formed on the surface. The higher is the grinding feed, the higher is the temperature in the cutting zone, and hence, the greater is the tensile residual stress value. It may be determining for the EWF increase.

REFERENCES

[1] Malyshev E.N., Musokhranov M.V., Kalmykov V.V., Antonyuk F.I. Distribution of energy of technological influence during the formation of working surfaces of machine parts from metallic materials. Modern problems of science and education. 2015. No. 1-1. P. 58.

[2] Musokhranov M.V., Kalmykov V.V., Malyshev E.N., Zenkin N.V. Energy of the surface layer of metals as an instrument of influence on the value of the coefficient of friction // Fundamental studies. 2015. № 2-2. Pp. 251-254.

[3] Skriver H. L., Rosengaard N. M. Surface energy and work function of elemental metals // Physical Review B. 1992. V. 46. №. 11. Pp. 7157.

[4] Musokhranov M.V., Antonyuk F.I., Kalmykov V.V. Surface energy and the process of seizing contacting surfaces // Science and Education: a scientific publication of the MSTU. N.E. Bauman. 2014. No. 11. P. 45-51. DOI: 10.7463 / 1114.0737377.

[5] Kalmykov V.V., Musokhranov M.V., Logutenkova E.V., Malyshev E.N., Gorbunov A.K. Generation of surface energy in metals using row-by-row microdeformation // International Journal of Applied Engineering Research. 2017. T. 12. № 24. p. 15621-15626.

[6] Musokhranov M.V., Kalmykov V.V., Malyshev E.N. Experimental research of variability of surface energy value of FE37-3FN, C45 and 41CR4 steels // International Journal of Applied Engineering Research. 2017. T. 12. № 17. p. 6428-6433.

[7] Musokhranov M.V., Antonyuk F.I., Kalmykov V.V. Determination of the value of the surface energy through the work function of the electron // Modern problems of science and education. 2014. № 6. P. 134.

[8] Musokhranov M.V., Kalmykov V.V., Gerasimova N.S., Malyshev E.N. Residual stresses in the energy theory of the process of grasping the surfaces of machine parts // Fundamental research. 2015. No. 12-2. Pp. 311-314. DOI: 10.17513 / fr.39411.

[9] Kunin LL Surface phenomena in metals. M., GNITL

on ferrous and non-ferrous metallurgy, 1955. 304 p.

[10] Antonyuk F.I., Kalmykov V.V., Fedorov V.A. Influence of the roughness of the original surface on the force of diamond smoothing // Science and Education: a scientific publication of the MSTU. N.E. Bauman. 2014. No. 12. P. 171-180.

[11] Madyira D., Laubscher R. F., N. Janse van Rensburg and Henning P. F. High speed machining induced residual stresses in Grade 5 titanium alloy // Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials Design and Applications, vol. 227, no. 3, pp. 208 -215, 2013. DOI: 10.1177/1464420712462319.

[12] Levitin V. V. et al. Influence of cyclic stresses upon the electronic work function for the metal surface // Solid state communications. 1994. V. 92. №. 12. Pp. 973-976.

[13] Hölzl J., Schulte F. K. Work function of metals //Solid surface physics. – Springer Berlin Heidelberg, 1979. Pp. 1-150.

[14] Hua G., Li D. The correlation between the electron work function and yield strength of metals //physica status solidi (b). 2012. V. 249. №. 8. Pp. 1517-1520.

[15] Li W. et al. Influences of tensile strain and strain rate on the electron work function of metals and alloys // Scripta materialia. 2006. V. 54. №. 5. Pp. 921-924.

[16] Lu H., Hua G., Li D. Dependence of the mechanical behavior of alloys on their electron work function — An alternative parameter for materials design // Applied Physics Letters. 2013. V. 103. №. 26. Pp. 261902.

[17] Zharin A. L., Fishbejn E. I., Shipitsa N. A. Effect of contact deformation upon surface electron work function // Journal of friction and wear c/c of trenie i iznos. 1995. V. 16. Pp. 66-78.

[18] Zharin A. L., Rigney D. A. Application of the contact potential difference technique for on-line rubbing surface monitoring (review) // Tribology Letters. 1998. V. 4. №. 2. Pp. 205-213.