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Performance Potential of Grinding Tools on Flexible Backing Produced of Grains with the Controlled Form

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Abstract. The paper provides consideration to the approaches to designing new grinding tools on flexible backing – flap grinding wheels and grinding belts having abrasive grains with certain form and orientation in their structure. Methods to estimate the shape of abrasive grains have been analyzed. Experimental data has been presented how the form of a grain affects characteristics of tools on flexible backing. Recommendations on practical application of new tools have been given

1. Introduction

At present a great number of papers deal with the effect of grain form on the process of cutting. The results of these investigations emphasize the importance of «form factor» of an abrasive grain [7, 11, 20, 21, 23, 24]. In view of these results an assumption has been made designing new constructions of grinding tools on flexible backing using abrasive grains classified according to their form will be an urgent issue in the long-term outlook.

An integrated approach to investigation into the influence of abrasive grain form on operating characteristics of grinding tools on flexible backing made a detailed consideration of all phases in their life cycle possible. In particular, a wide range of problems focused on the analysis of single abrasive grains were solved, as well as issues of testing their cutting capacity and strength, manufacturing a preproduction batch of tools having a patent on invention, and investigating their properties were studied.

2. Methods of research

Let us follow main phases of our work.

As far as we know, abrasive grains get any shape provided that the production process of grinding grains involves fragmenting ingots of abrasive material with any machines proceeded by sieving. The form can vary greatly: disk-shaped (needle-shaped) to isometric (sphere-shaped) variants [6]. When it comes to abrasive materials the grain is shaped in the course of production in dependence on chemical composition and dimensions of the ingot to be molten, conditions of cooling and grinding etc. The influence of these parameters is important for form and geometry of a grain when grinding an ingot of abrasive material.

An up-dated oscillating separator [1, 7] and an electrostatic separator were applied to sort out equiform grain fractions from the mass of standard abrasive material. The principle of oscillating separator operation is shown below as an example (Figure 1). Precisely-sized abrasive material subject to separation is supplied evenly from the proportioning feeder 1 to the oscillating head 2. The grains of abrasive material 3 driven by directed oscillations from the vibration exciter and under own gravitational and frictional forces move on the oscillating head. Less coarse round particles, the so-called isometric grains, roll down on the surface into the corresponding collector-containers 4. Intermediate-formed grains move mainly in crosswise direction and are collected in the side containers. Disk-like and needle-shaped are raised on the inclined surface and get to the upper collector-containers.

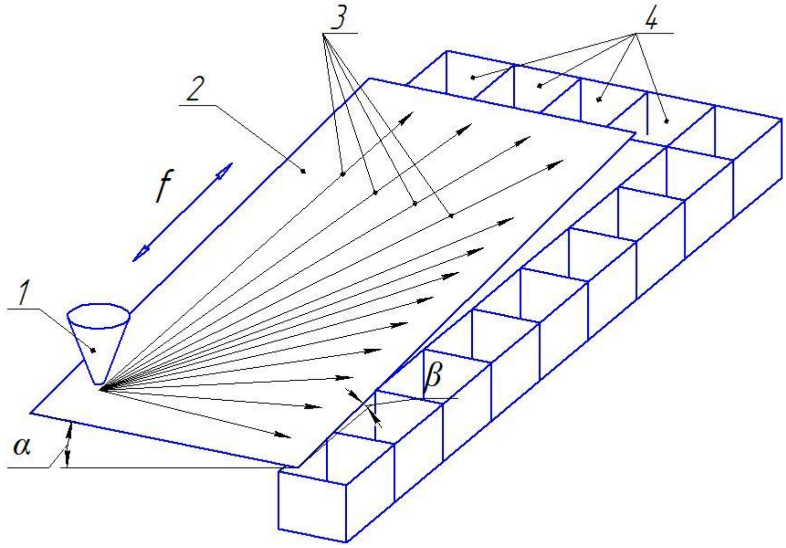


Figure 1. Form-based distribution of grinding grain on the oscillating head

After separation the form of each grain fraction was further evaluated on the base of quantitative and qualitative principles [23].

The qualitative evaluation procedure of a grain form involves grouping grains according to their forms. Three groups are divided: isometric, intermediate and needle (disk)-shaped. The qualitative evaluation procedure of a grain form has the advantage of promptness, although subjectivity of classification is its typical shortcoming as the form of a grain, which is a solid body, is evaluated according to the only projection. In view of this fact methods of qualitative evaluation can be recommended exclusively for the primary analysis of abrasive grains.

Methods of quantitave evaluation are more preferable to investigate how the form of a grinding grain affects the operational characteristics of grinding tools as they rely on specifying the parameter «form factor» K_f; its calculation necessitates a grain projection on the horizontal surface [15]. The most accepted approaches to specify the form factor are given below:

Form factor is calculated as a ratio of maximal length of a projection (l) to its breadth (b):

$$K_f = \frac{l}{b}. \tag{1}$$

Another approach to determine form factor is to calculate a ratio of a circle circumscribed around the grain projection (D) to the circle inscribed in it (d):

$$K_f = \frac{D}{d}. \tag{2}$$

Mentioned above methods to specify form factor take horizontal projection of a grain into consideration, that is why, inaccuracy of analysis is possible.

The evaluation procedure of a grain form involving analysis of horizontal and lateral projections provides exacter measuring results, eliminates inaccuracy as if compared with methods of grain form assessment based only on horizontal surface. The diagram of evaluation procedure of an abrasive grain form on the base of two projections is presented in Figure 2.

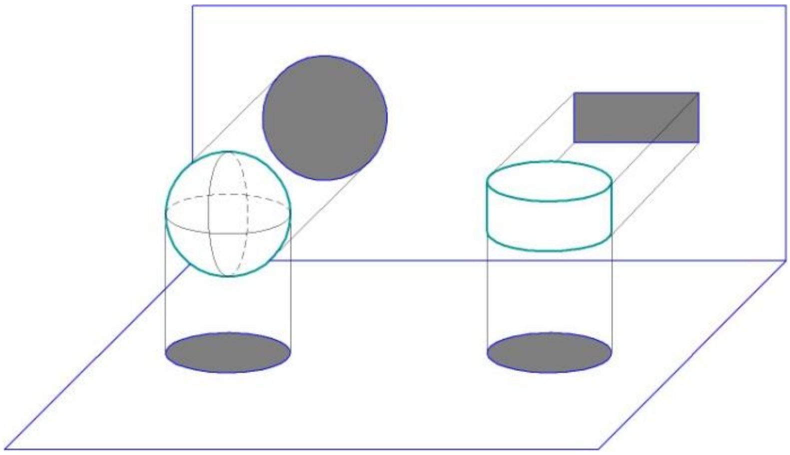


Figure 2. Evaluation of a grain form according to horizontal and lateral projections

Here, the quantitave characteristic of a grain form is described by the formula:

$$K_f^v = \frac{K_f^h}{K_f^l}. \tag{3}$$

where K_f^v - volume form factor;

K_f^h - form factor of a horizontal projection;

K_f^l - form factor of a lateral projection.

Cutting capacity, impact and static strength of single abrasive grains from each sorted out fraction were tested besides the evaluation of «form factor» parameter. As the result, regularity was revealed: both form and orientation angle of abrasive grains influence on their cutting capacity and impact strength [12, 22].

After required quantity of equiform abrasive grains had been sorted out, preproduction batches of grinding tools on flexible backing were made – flap grinding wheel and belts [5, 14]. Comprehensive studying the influence of a grain form on operational characteristics required three groups of tools produced in terms of State Standards. Precisely-sized grains were in the structure of the tools – isometric grains (mean form factor $K_f \approx 1.2$), intermediate ($K_f \approx 1.6$) and needle-shaped ones ($K_f \approx 2.2$).

Figure 3 demonstrates an operating section of a flap grinding wheel and a grinding belt. Structure numbers:

1 – flexible cloth backing,

2 – layer of coupling material,

3 – maker coat of adhesive material basic,

4 – size coat of adhesive material,

5 – abrasive grains with specified form.

With the purpose to improve cutting manufacture of preproduction batches of grinding tools involved electrostatic orientation of abrasive grains with the certain form on the flexible backing surface, performed by specially designed appliance and according to the original technology. The structure of this appliance makes possible full simulation of industrial technological process of abrasive cloth manufacture in laboratory conditions; moreover, its advantages are compactness, simplicity of construction, multifunctionality and flexibility. Furthermore, this appliance provides a possibility of coating grains by electrostatic filed with various inclination angels to the backing surface as opposed to the industrial production line.

Preproduction batches of tools on flexible backing were subject to abrasion and cutting capacity tests in order to identify the influence of grinding grain form on operational characteristics; roughness of the processed surface, temperature in the zone of cutting and forces of cutting when grinding were studied as well [8, 9, 10, 16, 17].

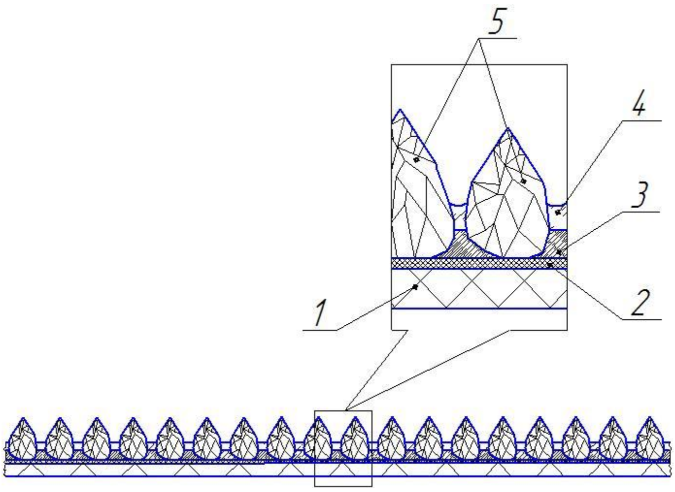


Figure 3. A section of a tool on a flexible backing produced of oriented grains with the controlled form

Grinding by a tool on a flexible backing is noted to be a complex and unstable phenomenon depending on numerous factors: properties of abrasive material and its granularity, characteristics and hardness of bonding material, features of a flexible backing, geometry of the tool, types and mode parameters of grinding etc. All the above mentioned is relevant both for flap grinding wheels and grinding belts as flexible backing amends grinding process and makes these tools different from dimensionally-stable grinding tools – cutoff and rough grinding wheels, bars, segments etc. [3, 4, 13, 18].

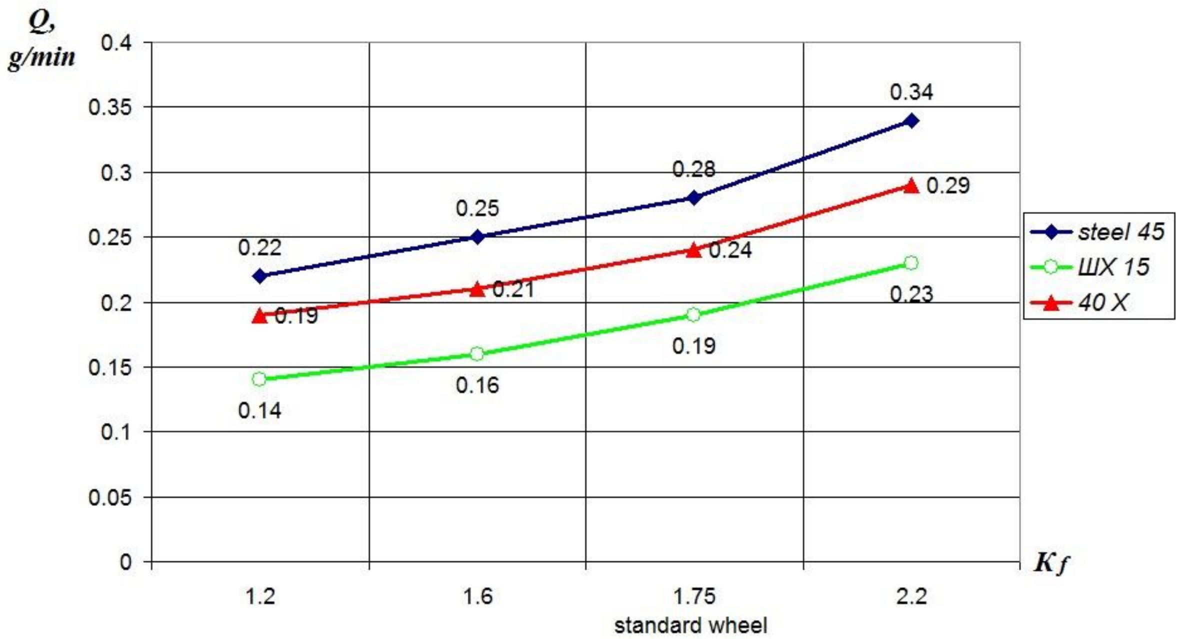
Operational characteristics of experimental grinding tools on flexible backing were tested by flat surface grinder 3G71.

The research was focused mainly on the effect abrasive grain form has on output parameters, models reliably for describing mechanisms of the processes were used for mathematical treatment. Form factor (K_f) of a grinding grain was used as an input variable parameter.

Mathematical treatment of obtained experimental data was performed with the software «STATISTICA 6.0» by means of stochastic simulation based on multiple correlation method. This software allowed processing experimental data set automatically and investigating into the dependence of input grinding parameters to the form factor (K_f) of a grinding grain [2, 7].

3. Results and discussion

A number of dependences experimentally obtained in the course of experimental flap grinding wheels are given below (Figure 4, 5).



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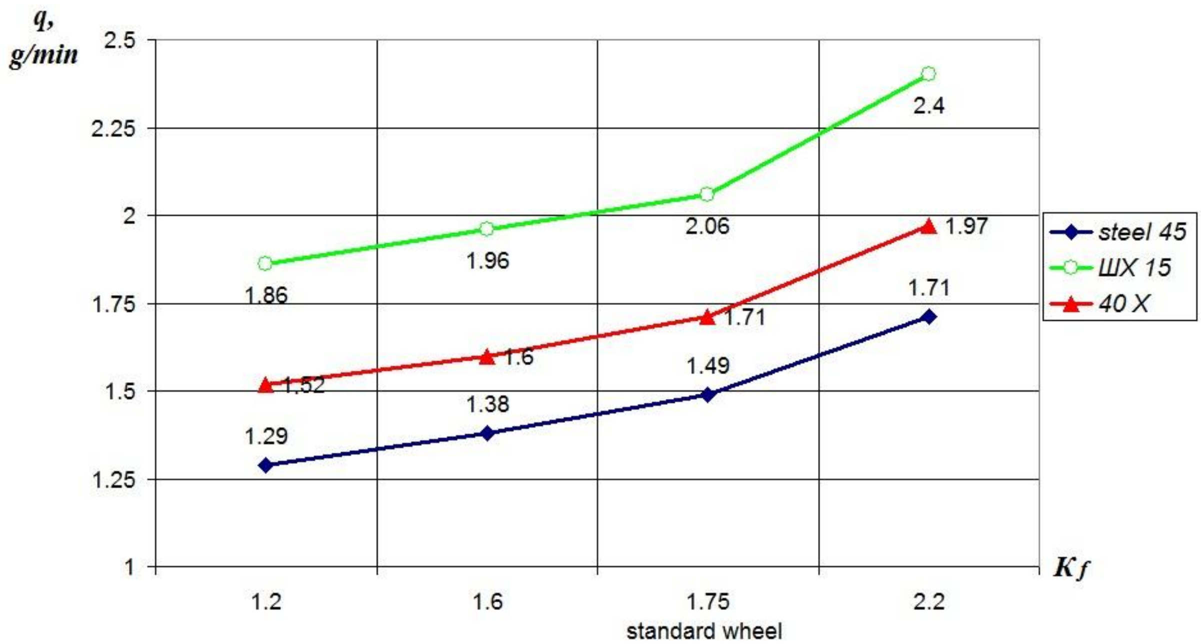

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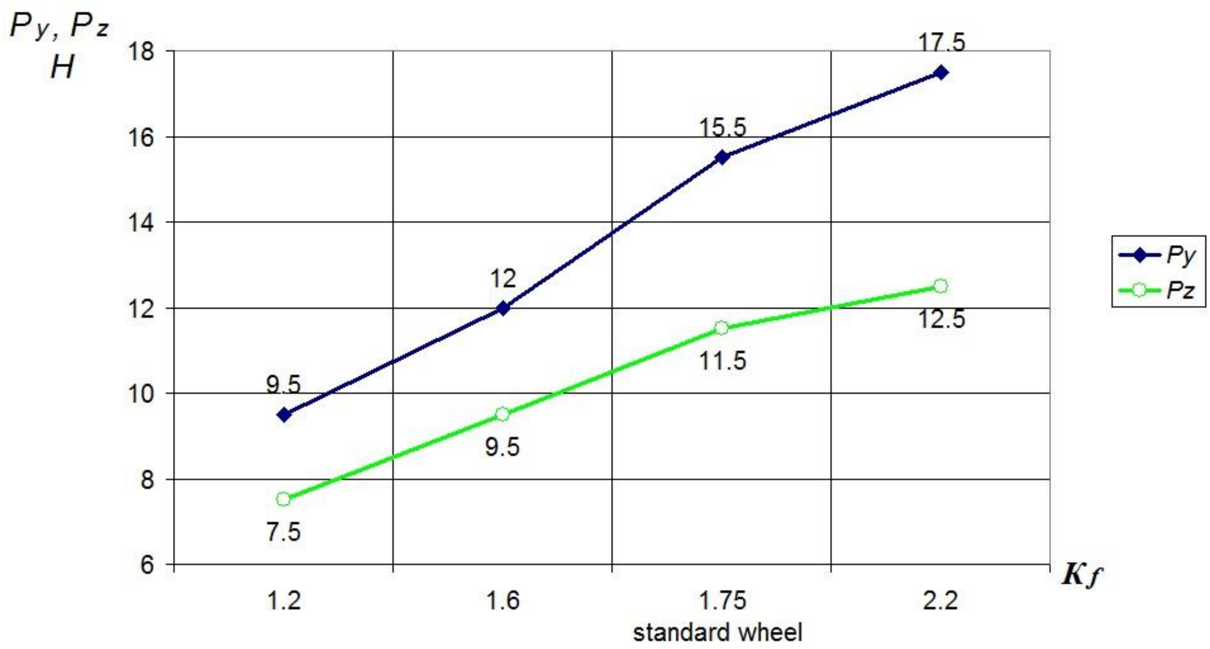
Figure 4. The dependence of cutting capacity *a)* and wear *b)* of a flap grinding wheel on form factor of a grinding grain when machining various steels

Given below results were obtained in the course of experiments [17, 19]:

1. When passing from the isometric (K_f = 1.2) to the needle-shaped (K_f = 2.2) form of grains in the structure of a flap grinding wheel, there is a monotonic increase by the factor of 1.56 in the curves of cutting capacity nearly for all steels. When passing from grains (K_f = 1.2) to the standard wheel (K_f = 1.75) cutting capacity increases to a very little degree, approximately by the factor of 1.29. In the range K_f = (1.75÷2.2) cutting capacity tends to a slight increase.

With regard to the applied grain form cutting capacity goes down by the factor 1.51 on the average when increasing the hardness of machined half-product, that is, when passing from steel 45 (HB 187) in as-received state to the tempered ШХ 15 (HRC 65).

2. Wear of flap grinding tools when changing isometric grain form ($K_f \approx$ 1.2) in needle-shaped grains ($K_f \approx$ 2.2) goes up proportionally by the factor of 1.3. When passing to the grinding wheels produced according to the ordinary technology ($K_f \approx$ 1.75) wear rises to a little degree – 1.12 times on the average, this trend is more or less relevant for machining all grades of steel.



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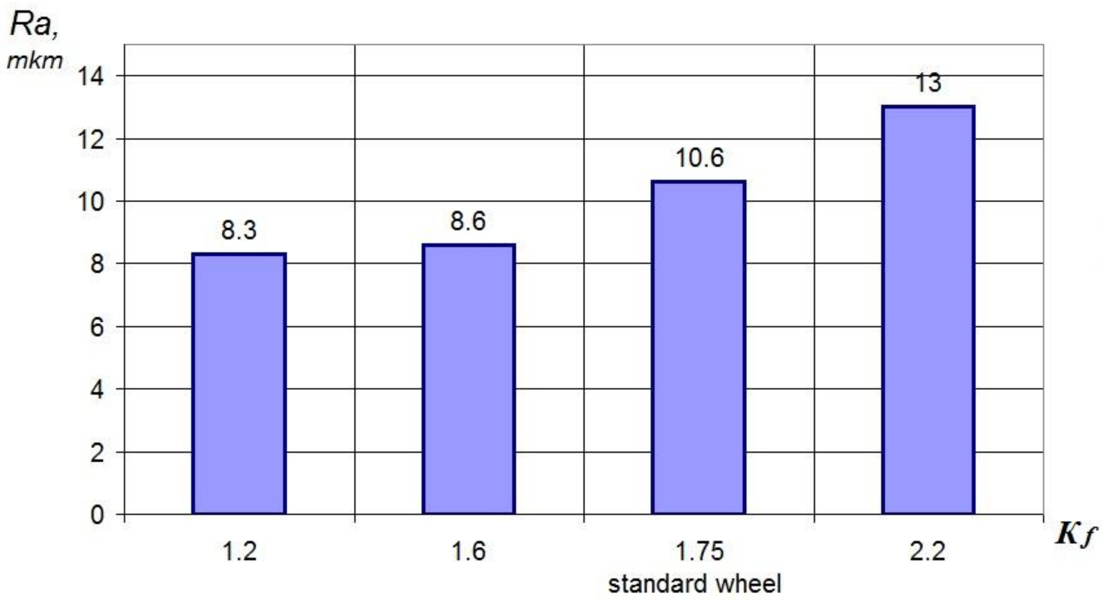

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Figure 5. The influence of form factor of a grinding grain on:
a) cutting force components and *b)* roughness of the grinded surface

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3. Evaluated force dependences of experimental flap wheel grinding demonstrate radial component of cutting force goes up by the approximate factor of 1.8, and its tangential component grows by the factor of 1.66 when passing from the wheels with isometric form of grains *(*K_f = 1.2*)* to wheels with needle-shaped grains *(*K_f = 2.2*)*.

4. On the ground of obtained data we came to a conclusion flap wheel grinding is distinguished by low temperature in the zone of cutting due to the design features of these tools, low loads of grinding and effect of ventilation. The maximal registered difference in absolute values of temperature for wheels with isometric and needle-shaped grain forms is not significant, approximately 15 – 20 ºC for applied modes of grinding.

The increase in hardness of the half-finished product to be grinded causes temperature rise in its surface layer by the factor of 1.2 on the average for all kinds of experimental wheels.

5. The quality of the surface is better if grinded with wheels having isometric grains in their structure as opposed to wheels with needle-shaped grains. When grinding samples of steel 45, the difference in roughness R_a is 36% for wheels with form factors K_f = 1.2 and K_f = 2.2, respectively. As opposed to the standard wheel roughness of needle-shaped grains amounts to 18.5 %, whereas isometric grains cause 17.5% decrease in roughness.

4. Conclusions

The results obtained in the course of experiments allow offering the following recommendations on more efficient use of newly designed grinding tools on flexible backing:

- tools made of grains with higher K_f (that is, needle-shaped and disk-shaped grains) are recommended to use for snagging and preliminary operations;
- tools with lower K_f (that is, isometric form of grains) can be applied for finishing operations requiring for high quality of the surface to be grinded [15, 17-20].

To sum up, operating characteristics of grinding tools on flexible backing can be improved significantly, as well as their potential can be used to the full provided that the most appropriate form and orientation of grinding grains are selected.

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