Study of the working face of a flexible grinding tool

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Abstract. The technology of grinding with a flexible abrasive tool is a rather complicated process, the characteristics of which are interconnected with the relief parameters of the surface abrasive coat of a tool. However, when forming the relief of the surface abrasive coat of a flexible grinding tool by popular methods, an unnecessary expenditure of expensive abrasive material occurs and the working face is obtained with randomly arranged abrasive grains, the processing performance of which can be assessed only taking into account some average values. As a result, some grains arbitrarily located on the surface of a tool partially or completely do not participate in the cutting process. The article is devoted to the issue of the study of the working face of a flexible grinding tool. Comparative tests of existing and developed methods for determining the number of abrasive grains on the tool face are presented. Experimental data on the influence of the angle of orientation of abrasive grains on their distribution density are presented.

1. Introduction
The grinding process with a flexible abrasive tool is influenced by a number of physical and technological factors, such as physical and mechanical properties of a workpiece, the parameters of the cutting face of an abrasive tool, contact area, pressure, shape and dimensions of the processed surface, etc. [1-3].

The cutting face of sandpaper can be characterized by such key parameters as the grain size, the number of grains located on a surface unit, their depth and orientation relative to the backing, the distance between grains and grain geometry [4-7]. Also, the grinding process depends on the grade and uniformity of the abrasive material, the physical and mechanical parameters of the bond.

In turn, the random arrangement of abrasive grains on the working face of a flexible grinding tool does not allow to precisely solve the task, and in practice, methods of approximate and statistical calculations are used.

To assess the condition of the cutting face of sandpaper, experiments of contact marking of grinding grains were carried out in [8]. To obtain marks, the sandpaper was pressed with a steel roller to a bag composed of thin sheets of foil, which were fixed on a rigid backing. The results obtained are presented in figure 1.

In the work of M.A. Zaitseva [9], the estimated number of abrasive grains per 1 cm² of area ranges from 300 to 1643 for a grain size of 40÷16 depending on the coat density.

An analysis of the literature showed that the number of abrasive grains per 1 cm² determined by experimental and computational methods is very different.
This is because the computational methods do not take into account the shape of each grain, but use an approximate model for calculations. In turn, experimental methods based on the use of foil show data only on the most projecting grains.

2. Methods and researches

To eliminate the difference between experimental and computational methods, a method was developed to determine the number of abrasive grains on the working face of grinding tools. This method is based on taking a polyisobutylene impression followed by CorelDRAW image processing.

To prove the suitability of this method, a study was made of the working face of the standard sandpaper with different grain sizes. The purpose of the study is to determine the number of abrasive grains on the working face. For comparison, methods based on the use of foil and carbon paper were also used.

To study the influence of the angle of orientation of abrasive grains on their distribution density, an electrostatic installation was designed. A scheme of the process of applying abrasive grain under the influence of an electrostatic field is shown in figure 2.
Electrostatic application of abrasive material is described by three successive stages:

Stage 1 - charging of grains and their subsequent orientation along the major axis in an electrostatic field;

Stage 2 - tearing off the surface of the electrode and the flight of charged grain under the influence of an electrostatic field;

Stage 3 - contact and penetration of grain into the backing bond.

A batch of experimental samples with different orientation angles of abrasive grains relative to the backing was made at the designed installation. Orientation angles were 90º, 75º, 65º, 60º.

3. Results and discussion

The results of the study of the working face of the standard sandpaper are presented in tables 1-3.

**Table 1.** The results of the study of contact carbon paper marks.

| Grain size, μm | 160 | 250 | 400 |
|---------------|-----|-----|-----|
| Image         | ![Image](image1.png) | ![Image](image2.png) | ![Image](image3.png) |
| Number of grains per 1 cm² | 110 | 83  | 32  |

**Table 2.** The results of the study of contact foil marks.

| Grain size, μm | 160 | 250 | 400 |
|---------------|-----|-----|-----|
| Image         | ![Image](image1.png) | ![Image](image2.png) | ![Image](image3.png) |
| Number of grains per 1 cm² | 106 | 72  | 39  |

**Table 3.** The results of the study of contact polyisobutylene impression marks.

| Grain size, μm | 160 | 250 | 400 |
|---------------|-----|-----|-----|
| Image         | ![Image](image1.png) | ![Image](image2.png) | ![Image](image3.png) |
| Number of grains per 1 cm² | 656 | 475 | 231 |

As can be seen from the tables, the number of projecting abrasive grains decreases; the grain size being increased. The data obtained using carbon paper and foil has close values and almost do not differ. This suggests that these two methods allow getting information only about the highest grains, i.e. most active. Therefore, for a more detailed assessment of the number of grains on the working face of a grinding tool, the most suitable method is the one based on the use of a polyisobutylene impression, since its results are confirmed by theoretical computations of many authors.

If, when studying the influence of the angle of orientation of abrasive grains on their distribution density, it is agreed that the number of visible abrasive grains is 100%, then the proportion of the oriented grains of each test sample can be determined. The results are presented in table 4.
Table 4. The proportion of the oriented abrasive grains on the backing surface of the experimental samples.

| The angle of orientation of the abrasive grains relative to the backing, degrees | Grain size 200 μm | Grain size 400 μm |
|---|---|---|
| 60 | 68 | 61 |
| 65 | 72 | 66 |
| 75 | 80 | 74 |
| 90 | 91 | 88 |

Analyzing the data obtained, we can draw the following conclusions:

- the orientation of the abrasive grains on the backing surface is influenced by an electrostatic field; in addition, the density and orientation are affected by field strength vector;
- the optimal angles of grain orientation by the electrostatic method are ranged from 75° to 90°, since the grain orientation is welded in the range of 80-91% of the total.

The method of taking a polyisobutylene impression was used to study the working face of the experimental samples. The sandpapers with 40 grit grains and orientation 90°, 75°, and 60° were used as samples. The resulting impressions are shown in table 5, and the results of the study are presented in table 6.

Table 5. The resulting impressions.

| Orientation angle, degrees | Sample №1 | Sample №2 | Sample №3 | Sample №4 | Sample №5 |
|---|---|---|---|---|---|
| 90 | ![Image](image90.png) | ![Image](image90.png) | ![Image](image90.png) | ![Image](image90.png) | ![Image](image90.png) |
| 75 | ![Image](image75.png) | ![Image](image75.png) | ![Image](image75.png) | ![Image](image75.png) | ![Image](image75.png) |
| 60 | ![Image](image60.png) | ![Image](image60.png) | ![Image](image60.png) | ![Image](image60.png) | ![Image](image60.png) |

Table 6. The results of the study of the influence of the orientation of abrasive grains on their distribution density.

| Orientation angle, degrees | Sample №1 | Sample №2 | Sample №3 | Sample №4 | Sample №5 | Average value |
|---|---|---|---|---|---|---|
| 90 | 262 | 285 | 265 | 265 | 266 | 269 |
| 75 | 254 | 255 | 248 | 253 | 248 | 252 |
| 60 | 205 | 218 | 186 | 219 | 216 | 209 |
In the Table it is shown that:

- the largest number of grains is obtained when an electrostatic field is oriented at an angle of 90° to the backing surface;
- the distance between the electrodes increasing; the concentration of grains in the experimental samples decreases;
- The results of studying the number of grains by taking impressions of the standard sandpaper and the experimental sample are almost identical, and this once again proves that the method of taking a polyisobutylene impression is reliable.

4. Conclusions
An analysis of the literature showed that the number of abrasive grains per 1 cm² determined by experimental and computational methods is very different, because computational methods do not take into account the shape of each grain, but use an approximate model for calculations, and experimental methods based on the use of foil show data only for the most projecting grains. The method for studying the working face of a flexible grinding tool presented in this paper, based on taking a polyisobutylene impression and its subsequent analysis is devoid of this drawback, because its results are confirmed by theoretical computations of many authors.

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