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APPLICATION OF THE LASER SCANNING MICROSCOPY TO EVALUATION OF ABRASIVE TOOL WEAR

Grinding is one of the basic precise machining methods. Evaluation of the abrasive tool surface is the basic criterion of forecasting the tools' durability and the process results. The applied method of laser scanning made determination of the surface coordinates and subsequently of its geometric features with micrometric accuracy possible. Using the information on the abrasive tool surface geometric structure, a methodology of evaluation of the level of changes of the tool during the machining process was developed. The developed method allowed for evaluation of the level of abrasive tools' wear, and subsequently formed foundations for assessment of the influence of the machining parameters on the durability of abrasive tools, evaluation of the influence of the parameters of the process of shaping the abrasive tools' active surfaces on their geometric characteristics and evaluation of the level of correlation between the monitored process parameters and the degree of the abrasive tools' wear.

1. INTRODUCTION

Grinding is one of the basic precise machining methods. Abrasive and shape wear of the abrasive tool, as well as loading of its active surface handicap the machining results. The loss of cutting capacity in abrasive tools or alteration of their primary shape influences the surface quality and precision of the workpiece dimensions and its shape. Evaluation of the abrasive tool surface is therefore the basic criterion in evaluation of the workpiece grindability, which, in consequence, influences the durability period of the abrasive tools.

The above issue gains importance in case of grinding difficult-to-cut alloys, widely applied in aviation, defense and medical industries due to their durability and resistance to surface degradation. Physical and chemical properties of such alloys reduce their machinability by significantly decreasing the abrasive tools' durability.

Increasing the abrasive tools' durability period requires proper selection of machining parameters and conditions. Selection of machining parameters and conditions is one of the fundamental tasks of systems supervising grinding processes. Monitoring changes of the

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abrasive tools' cutting capacity during the machining process forms the basis for the above selection.

The most often used [1-5] method of evaluating the abrasive tools' wear degree are indirect methods using the correlation of the abrasive tool active surface's wear degree and the monitored variables of the grinding process (i.e. components of the cutting force, acoustic emission, machining system oscillations, etc).

Determining those correlations entails application of measurement methods that allow for as precise evaluation of the abrasive tool's wear during the machining process as possible, and subsequently relating it to the monitored signals. One of the advantages of application of indirect methods is the possibility to monitor the condition of the abrasive tool during the machining process.

Another group consists of the direct methods. When it comes to direct measurements of the abrasive tool's surface topography the non-contact techniques are used most frequently. The realized research [6] proves high effectiveness of evaluation of the abrasive tool's surface wear performed on basis of images obtained using the scanning electron microscope (SEM). The application of SEM is, however, of little practical importance mostly due to the limitations concerning the sizes of the analyzed surfaces and the difficulties imposed by their application in automatic evaluation of the abrasive tool's condition. At present a large researcher group are focused on visual systems [7-11]. The basis of operation of such systems are processing and analysis of a signal that is proportional to the amount of light reflected from the abrasive tool's active surface.

The authors of the work presented an application of the laser scanning microscopy to evaluation of the abrasive tool's conditions on basis of analysis of the abrasive tool's measurement results, using the scanning system. The applied measurement system facilitated measurement of the whole surface of the abrasive tool directly on the work station with micrometric accuracy. Using information on the abrasive tool's topography, a method of detecting the flat areas was proposed.

2. MEASURING THE ABRASIVE TOOL'S ACTIVE SURFACE

A 3D scanner (Fig. 1) was used for acquisition of the dimensional image of the grinding wheel's active surface. The scanner uses structural light for measuring. The measured object is illuminated by a series of white light lines, thus creating a net of specific thickness, i.e. the so-called raster, on the measured surface. The distance between the lines in the raster defines the number of data obtained during a single measurement. The minimal range between the lines used for measuring the abrasive tool for the CCD 3296 × 2572 matrix was 11,59μm. The lines that created the raster on the surface yield to the shape of the measured object and are deformed.

Standards in the form of lined images are registered by two cameras, creating phase dislocations on basis of the sinusoidal distribution of intensity on the CCD detector. Independent 3D coordinates are automatically calculated for each pixel on basis of optical transformation equations. As a result of the above operations a cloud of points is obtained and the number of points is mostly dependent on the camera resolution. The geometric configuration of the detector and the distortion parameters are calibrated using photogrammetric methods.

Fig. 1. Triangulation white light scanner ATOS III SO (Small Object) on the laboratory post

The single images registered in this way are limited in relation to the size of the field observed through the lenses (lenses with fields sizes 170 × 130 × 130 mm and 38 × 29 × 15 mm were used). To acquire the areas invisible in the first shot location of the measurement head were changed in relation to the measured object (10 measurements were made in total per one area of the abrasive tool). The subsequent pictures of lines created in such a way were connected using points of reference.

The exemplary results of the measurement of an abrasive tool is presented in Figure 2.

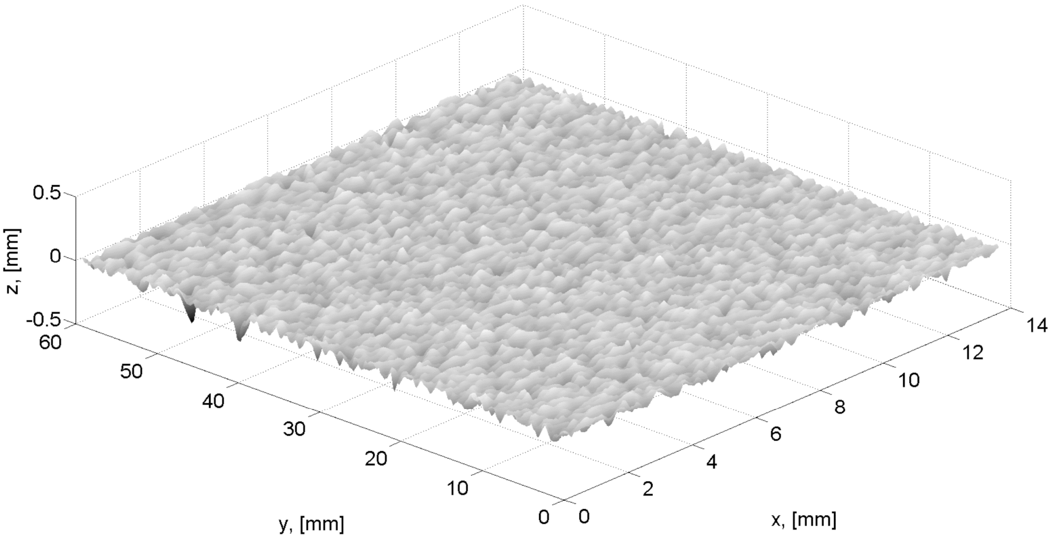


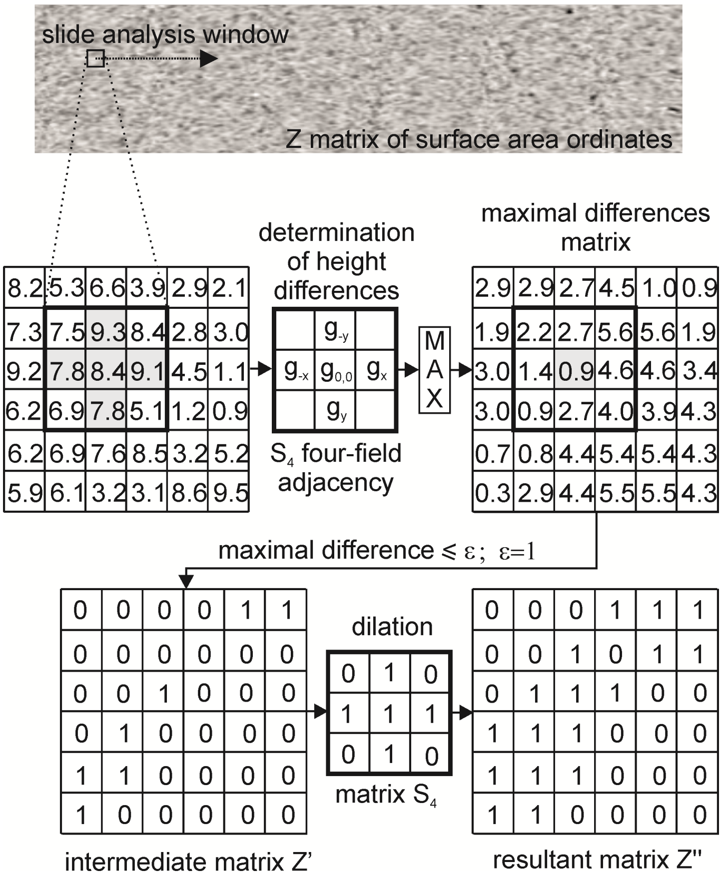
Fig. 2. Results of measurement of the abrasive tool’s surface using the laser scanning method

As a result of the measurements, after filtering off the abrasive tool’s shape, a matrix of Z ordinates describing the abrasive tool’s geometric structure was obtained. The matrix underwent subsequent transformations to determine parameters for evaluation of the abrasive tool’s wear during the machining process.

3. EVALUATION OF THE DEGREE OF ABRASIVE TOOL’S WEAR

Studies on the degree of the abrasive tool’s wear were conducted on the working station presented in Fig. 1. The process of wear of a grinding wheel with abrasive grains made of aloxite (Al_20_3) sized approximately 250µm placed in resinous bond was analyzed. The process was performed with a grinder for planes by down-grinding a sample with the grinding wheel circumference. The ground sample was made of steel with hardness 52HRC and sized 120 × 240mm, while the 0,02mm allowance was removed with longitudal feed 10m/min and transverse feed 2mm to cross the table. Having removed the total allowance of 0,1mm the abrasive tool’s condition was measured.

Flat areas present on the surface of the abrasive tool result mainly from the abrasive wear of grains and loading of the grinding wheel’s surface [12],[13]. The proposed pattern of detecting the flat areas is presented in figure 3.



8.2	5.3	6.6	3.9	2.9	2.1
7.3	7.5	9.3	8.4	2.8	3.0
9.2	7.8	8.4	9.1	4.5	1.1
6.2	6.9	7.8	5.1	1.2	0.9
6.2	6.9	7.6	8.5	3.2	5.2
5.9	6.1	3.2	3.1	8.6	9.5

2.9	2.9	2.7	4.5	1.0	0.9
1.9	2.2	2.7	5.6	5.6	1.9
3.0	1.4	0.9	4.6	4.6	3.4
3.0	0.9	2.7	4.0	3.9	4.3
0.7	0.8	4.4	5.4	5.4	4.3
0.3	2.9	4.4	5.5	5.5	4.3

0	0	0	0	1	1
0	0	0	0	0	0
0	0	1	0	0	0
0	1	0	0	0	0
1	1	0	0	0	0
1	0	0	0	0	0

0	1	0
1	1	1
0	1	0

0	0	0	1	1	1
0	0	1	0	1	1
0	1	1	1	0	0
1	1	1	0	0	0
1	1	1	0	0	0
1	1	0	0	0	0

Fig. 3. The diagram for illustration of methodology of detection of flat areas for a four-field adjacency

The flat areas were detected using the slide analysis window sized 3 × 3. The difference of ordinates of the abrasive tool of the central element and the adjacent elements was determined in the analysis window (four-field adjacency matrix S_4 was used).

For the thus defined analysis window and the adjacency term, transformations compliant with the below logical filter were performed on the medium matrix Z':

$$Z'(x,y) = \begin{cases} 1 & \text{if } \max(\mathrm{G_H}) < \varepsilon \\ 0 & elsewhere \end{cases} \tag{1}$$

where: G_H – vector of absolute differences g of surface ordinates between the central element of the analysis window and the adjacent field,

ε – threshold value dependent on the geometric parameters of the grains.

As a result, the matrix Z' was obtained. Next the binary medium matrix Z' underwent dilation:

$$Z' \oplus S_4 = \{p + q : p \in Z' \wedge q \in S_4\}, \tag{2}$$

Results of detection of flat areas for subsequent conditions of the abrasive tool are presented in Fig. 4.

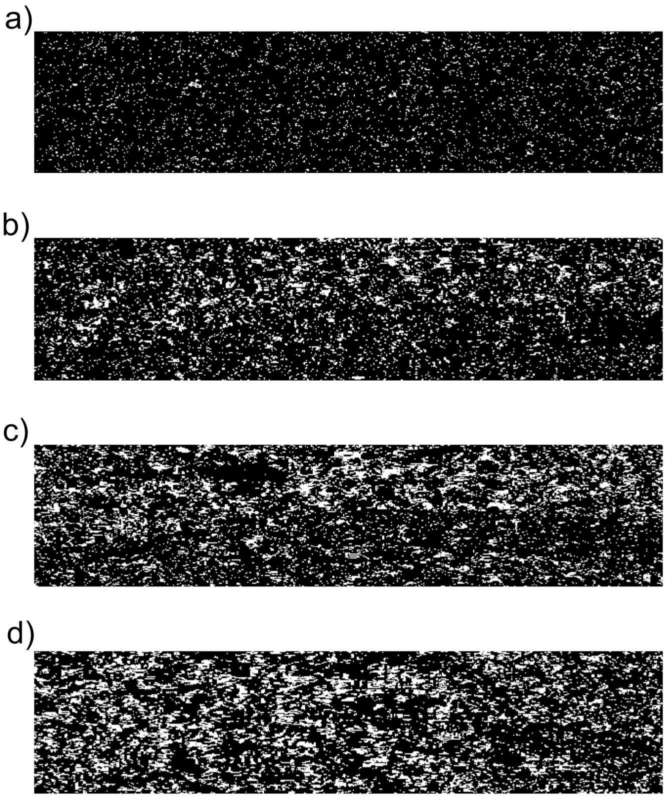


Fig. 4. Results of the detection of flat areas (white) on the abrasive tool's surface: a) the tool before the machining, b) after removing 2880mm^3, c) 5760mm^3, and d) 8640mm^3.

Next, segmentation and indexation of the flat areas was performed. In consequence, respectively 8226, 7366, 8362 and 7473 flat objects were separated for subsequent conditions of the abrasive tool. The generic field of the flat areas was respectively 4,73%, 13,02%, 17,67% and 22,17% of the abrasive tool's surface.

Regardless of the condition of the tool (volume of the removed material), the number of flat objects in the given range of ordinates did not increase. However, as the working time of the tool increased, the value of the generic field of flat areas in the given field of ordinates grew.

4. SUMMARY AND CONCLUSIONS

Application of spatial scanning systems in evaluation of the abrasive tool's condition enables it to be performed in industrial conditions directly on the work station. This offers the possibility of developing foundations for application of such devices in direct assessment of the abrasive tool's condition in automatic systems supervising the machining processes' quality.

The developed methodology of evaluation of the degree of abrasive tool's wear facilitates assessment of changes of the abrasive tool's surface that occur during the machining process. What was also developed were foundations for identification of flat areas that allow for detailed analysis of the forms of abrasive tool's wear.

The basic problem with assessing the condition of an abrasive tool's wear is developing a set of parameters for evaluation of their geometric structure, forming a complementary set, that guarantee high efficacy identifying the character of the abrasive tool's wear and easiness of the grade interpretation.

Development of synthetic indexes of evaluation of the condition of an abrasive tool's wear will allow for inclusion of the system of direct evaluation of the abrasive tool's condition into the grinding processes monitoring, optimization and supervision systems. It also forms the basis for developing models of correlations of machining parameters, measured process features and monitoring the quality of the machining process.

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