MORPHOLOGICAL ANALYSIS OF TRIANGULATED MODELS OF GRINDING WHEELS WORKING SURFACES

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ABSTRACT

Methods of obtaining and morphological analysis of a triangulated model of grinding wheels are described. The model is made from a set of photos of the investigated working surface of the wheels, which have a different spatial orientation of the depth field of image space while shooting.

INTRODUCTION

Maintaining of high cutting ability of wheels is one of main factors in ensuring of the grinding process effectiveness [1]. At researches and development of rational methods for shaping and maintaining of developed relief of grinding tools are different ways of recording and analyzing of its geometrical characteristics. These methods are divided into contact and contactless [2]. They have both advantages and disadvantages (limitations on accuracy, implementation complexity and costs). The stylus method disadvantage is distorting effect of sensing needle geometrical parameters on the reliability degree of results [3]. Laser scanning is devoid of such a drawback, but it cannot allocate the surface of grains and bonding material, and require expensive equipment [4]. Topography is also used, in the following ways: multifold stylus method [5]; sequential removal of sections [6]; application of multilayer coatings, differing in color or texture and removing thin section in level of the most prominent grains [7]; stereophotographing [8]. However, the method topography has not been enough distribution because of its complexity and large enough laboriousness.

Purpose of this article is to review the methodology for obtaining 3D model of the working surface of grinding wheels, which suitable for analysis of its characteristics in the morphological analysis system of triangulated models [9, 10], developed at department of integrated technology engineering named after M.F. Semko, NTU "KhPI".

METHOD OF FORMING OF 3D MODEL OF WORKING SURFACE OF GRINDING WHEEL

In the first phase, the implementing possibility of a methodology for obtaining 3D models of the working surface patch of grinding wheel by multiple photographs of the same area at different angles with Supereyes B008 digital USB-microscope and photos array combining in the 3D model is considered. When this approach is applied Autodesk 123D Catch program. When implementing of this approach, a device was used for the spatial orientation of the microscope relative to the investigated surface can be rotated around the optical axis of the focusing points for shooting at predetermined angles.

When macro-shooting of the grinding wheel working surface, deviation of the optical system axis from the investigated surface normal leads to the fact that a considerable part of the picture area extends beyond the image space sharpness depth (ISSD) [11]. The greater the deviation the smaller the area of the investigated surface in the sharpness zone. This problem was solved by using HeliconSoft Helicon Focus Professional. The program creates single focused image from several partially focused ones. This is accomplished by combining the focused areas.

In implementing the method of 3D model forming by receiving it of 10÷15 images photographed from different angles were set requirements to ensure the 3D model adequacy:

- mechanical system with 6 degrees of freedom must provide the spatial orientation of the microscope relative to a wheel working surface fragment with an accuracy of ± 10 microns on linear and ± 30' on angular displacement;

- to compensate for a small value of ISSD of the microscope optical system must each of the 10÷15 sharp images over the whole their area obtained from 4÷6, taken in a sequential displacement of ISSD field;

- in process of the shooting is necessary to maintain constant intensity and light angle on the test surface and to prevent glares and reflections [11].

The presence of these requirements determines the technical implementation complexity of the method. The application of this approach, owing to mechanical movements of the camera and step-by-step imaging, inevitably leads to accumulation of errors and reduction of the 3D model adequacy.

Reducing of errors influence on the fixing accuracy of initial data was achieved by minimizing of a microscope movement relative to the investigated surface patch of the tool and by reducing of the required number of shots to 4÷6. This approach has been implemented using HeliconSoft Helicon Focus Professional. Its essence is to simulate layered scanning of the surface relief by sequentially taking pictures with a step by step vertical displacement of ISSD field. Fig. 1 and 2 show the photographs of surfaces of ПВ 25А 40 80×63×20 СМ 2 abrasive wheel and АСВ 125/100 МВ1 100 diamond wheel.

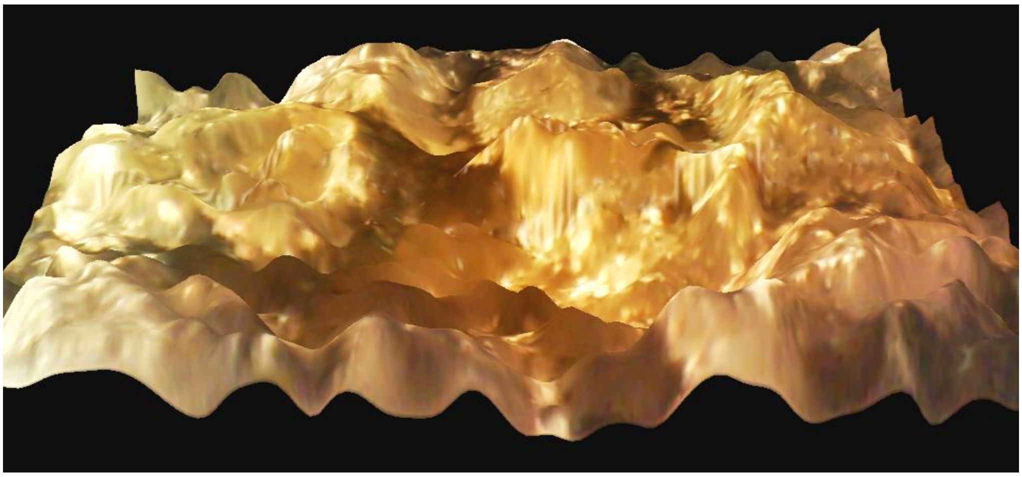

Fig 1
3D model of working surface of ПВ 25А 40 80×63×20 СМ2 abrasive wheel

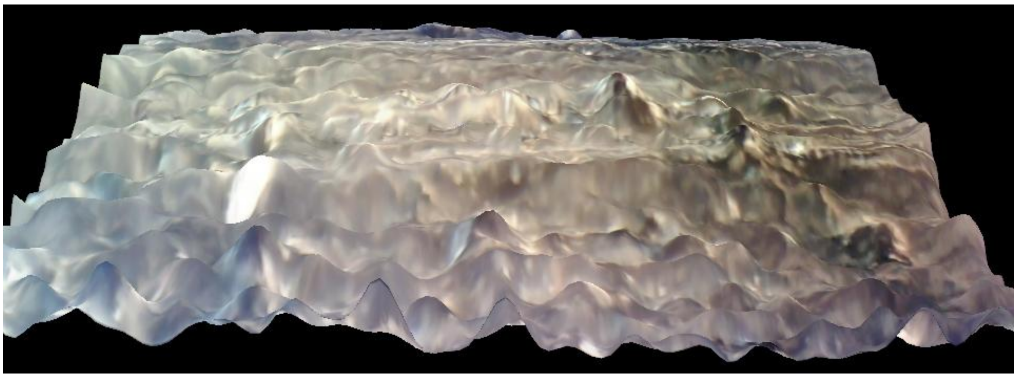

Fig 2
3D model of working surface of ACB 125/100 MB1 100 diamond wheel

Adequacy of obtained 3D models depends on the following main factors: resolution of digital matrix, resolvability and magnification factor of the optical system, and software features. The 3D model verification is done by analyzing the geometric characteristics of the shadows cast by relief peaks of the investigated area (fig. 3). Length l of the shadow is measured from a grain, which protrudes from the bonding material on height h, cast by a light source located at angle α to optical axis of the microscope. Taking into account multiplicity K of the microscope optical zoom, height of the protrusion grain above the bonding material can be calculated according to $h \approx l \cdot ctg\alpha \cdot K^{-1}$.

The main advantage of the proposed methodology is the ability to obtain 3D models adequacy of the grinding wheel surface at relatively low complexity of the implementation.

Fig. 4 shows a block diagram of a receipt of 3D model database of the working surface fragment of the grinding wheel.

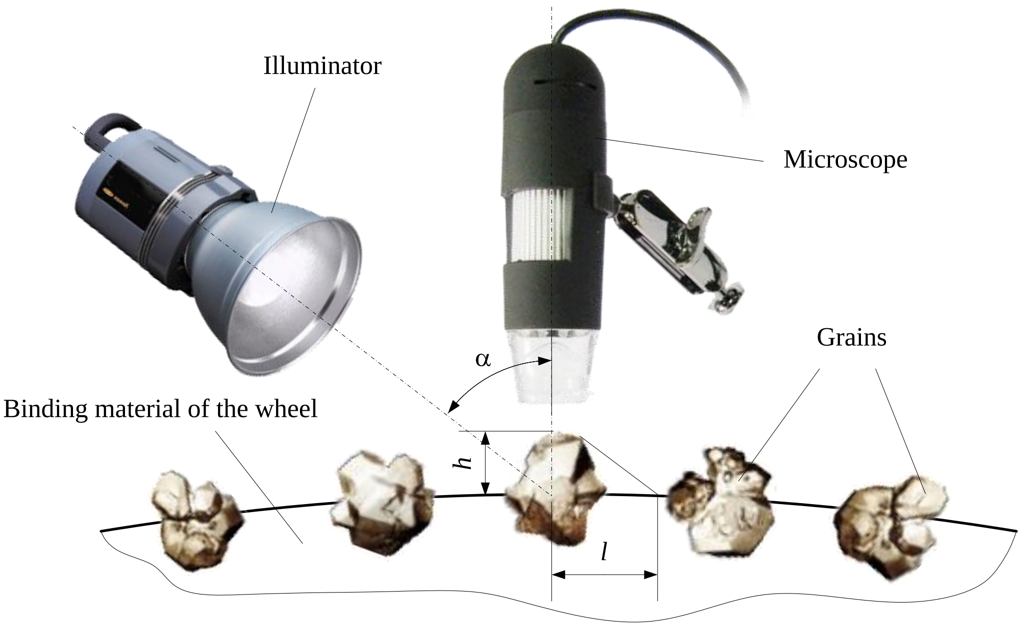

Fig 3
Scheme of determining the height of the protrusion grain above the bonding material

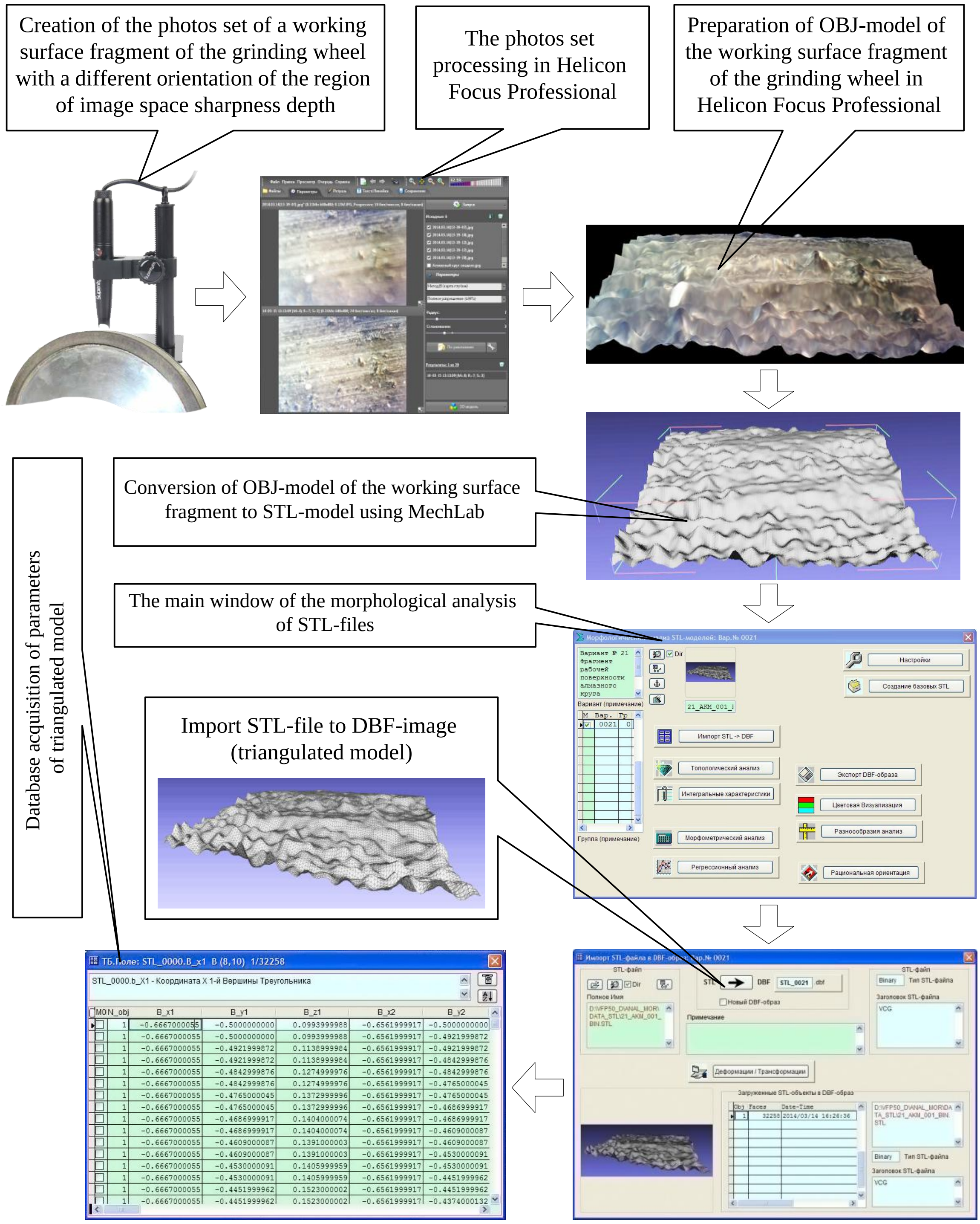

Fig 4
Block diagram of a receipt of triangulated model database of the working surface fragment of the grinding wheel

MORPHOLOGY ANALYSIS SYSTEM OF TRIANGULATED MODELS

Fig. 5 shows a main form of the morphological analysis. Applied to the study of 3D model of working surface fragment of the grinding wheel, the system allows realizing:

- STL-file conversion to DBF-image (fig. 6) with a given accuracy of rounding vertex coordinates;

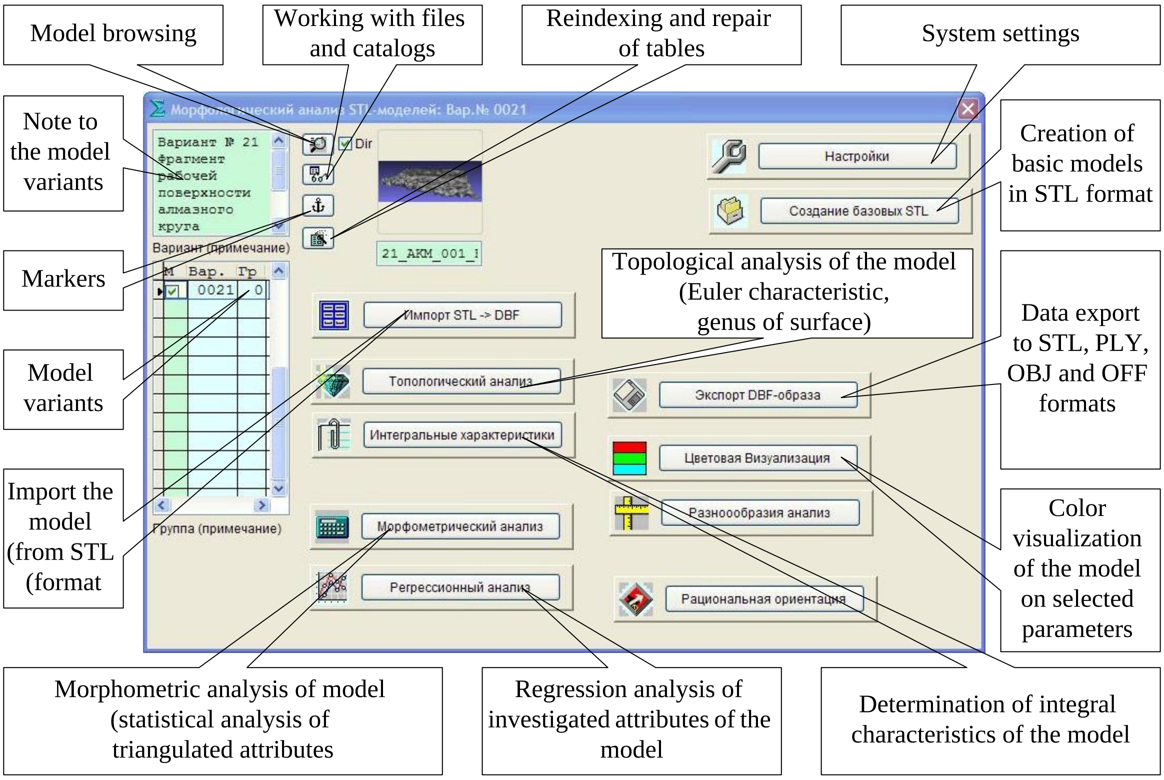

Fig 5

Main form of program of STL-models morphological analysis

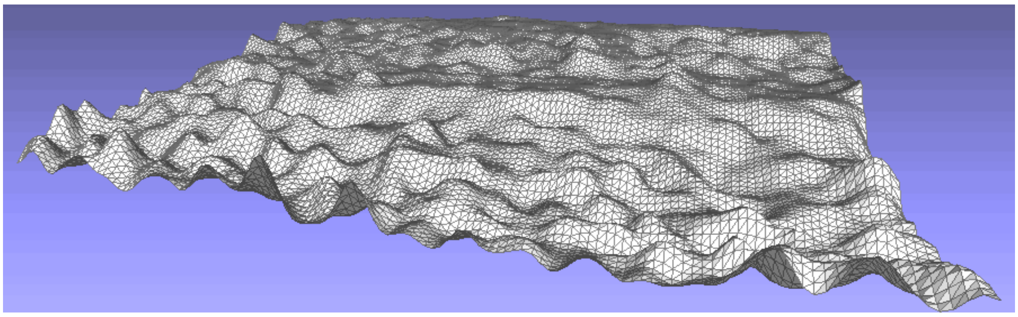

Fig 6

Triangulated model of ACB 125/100 MB1 100% diamond wheel working surface

- a topological analysis (a determination of the Euler-Poincare characteristic, a genus of the surface, an analysis of faces and edges adjacency);
- a definition of integral characteristics (linear, angular, surface and volume ones);
- a morphometric analysis of the model (a determination of statistical characteristics of the investigated attributes of vertices, edges and faces);
- correlation and function-regression analysis of relationships of studied attributes using a given set of regression equations;
- color visualization on given attributes;
- data export of DBF-image to STL, PLY, OBJ and OFF formats.

For estimating parameters of the longitudinal profile [12] of the working surface of the grinding tool in the system of morphological analysis is necessary to add a complex of investigated features to differentiate a height $t_в$ and a step $h_в$ of waviness by the 3D models. In this complex must enable characteristics to identify the regular changes in values of vertex coordinates of the model.

CONCLUSIONS

To obtain adequate 3D models of the surface of grinding tool rationally implement the methodology of layered photographing with the stepped displacement of a field of the image space sharpness depth of the optical system of the digital microscope. The morphological analysis system of triangulated models developed at the department of "Integrated technology engineering" of NTU "KhPI" allows to realize topological, morphometric and regression analysis of triangulated models to get their statistics and integral characteristics. It is planned to enhance the system by the analysis of morphometric characteristics of the working surface relief of the grinding tool.

REFERENCES:

[1] [MAMALIS A.G., KUNDRAK J., GYANI K.]: **The significance of continuous dressing in precision grinding of hard and brittle materials** // Materials and manufacturing processes. – Vol. 16. Is. 3. – P. 341-351. DOI: 10.1081 / AMP-100107379 2001.

[2] [VINESH RAJA, KIRAN J. FERNANDES] **Reverse engineering: an industrial perspective**. - London: Springer, 2008. - 242 p.

[3] [Popov S.A., Malevsky N.P., TERESHCHENKO L.M.] **Diamond-abrasive machining of metals and hard alloys**. – M .: Mechanical Engineering, 1977. – 263 p. – In Russian.

[4] [GRABCHENKO A.I., DOBROSKOK V.L., FEDOROVICH V.A.] **3D modeling of diamond-abrasive tools and grinding processes**: Textbook. – Kharkiv: NTU "KhPI", 2006. – 364 p. – In Russian.

[5] [DUNIN-BARKOVSKIY I.V., KARTASHOV A.N.] **Measurement and analysis of roughness, waviness and roundness of surface**. – M.: Mechanical Engineering, 1978. – 232 p. – In Russian.

[6] **Electropulse machining of metal** / [A.L. LIVSHITS, A.T. KRAVETS, I.S. ROGACHEV, A.B. SOSENKO]. – M.: Mechanical Engineering, 1967. – 294 p. – In Russian.

[7] **Study method of surface roughness**: A.c. 1054669 USSR, MKI G 01 B 5/28. / [V.L. DOBROSKOK, V.F. DROZHIN, A.I. GRABCHENKO, A.I. MIKHAILOV]. № 3360097/15-28; Declared 20.11.81; Published 15.11.83, Bulletin № 42. – 3 p. – In Russian.

[8] [SILVESTROV V.D.] **Crush roll dressing of grinding wheel**. – M.: Oborongiz, 1955. – 128 p. – In Russian.

[9] [DOBROSKOK V.L., FADEEV V.A. et al.] **Morphological analysis of triangulated models of industrial products** // Cutting and tool in technological systems. - Kharkiv: NTU "KhPI". – 2011. – Vol. 79. – P. 52-63. – In Russian.

[10] [DOBROSKOK V.L., ABDURAYIMOV L.N., CHERNYSHEV S.I.] **Integral characteristics of triangulated 3D models of products** // Cutting and tool in technological systems. - Kharkiv: NTU "KhPI". – 2011. – Vol. 80. – P. 92-101. – In Russian.

[11] [YASHTOLD-GOVORKO V.A.] **Photographing and photoproccessing. Shooting, formulas, terms, recipes**. Ed. 4th. – M.: "Art", 1977. – 343 p. – In Russian.

[12] **Abrasive and diamond materials processing: Handbook** / Ed. [A.N. REZNIKOV]. – M.: Mechanical Engineering, 1977. – 391 p. – In Russian.