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Grain size and three-dimensional particle shape – automatic analysis with application of optical electronic AWK 3D analyzer

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ABSTRACT: The knowledge and capability of measuring the grains size and three-dimensional (3D) particle shape is very important in basic research and in practice. This knowledge finds a lot of applications in a number of geology disciplines (sedimentology, petrology, mineralogy, hydrogeology, engineering geology, soil science, soil mechanics), and in the geotechnics, hydrotechnology and is frequently used in the analysis of geomaterials for various industries and applied in the building engineering or road engineering. Very time and labour-consuming measuring methods are used for these types of analyzes. The application of automatic measurements of the grains size and 3D particles shape with the use of the optical electronic AWK 3D analyzer, speeds up such measurements making them more accurate. The Zingg shape classification used for the analysis of the particles shape is commonly known and applied in testing and may successfully be used in practice. The results obtained pending measurements allow calculating a number of additional parameters of grains distribution necessary in the wide spectrum of tests and practice.

1. INTRODUCTION

The determination of the grains size and particles shape is essential for the scientific research and the application of the geomaterials for practical purposes (Giriat et al., 2007; Mycielska-Dowgiałło, 1995). In the worldwide literature, the Zingg shape classification (1935) is frequently used for analyzing the particles shape. On the grounds of this classification, four basic forms (shapes) of particles may be recognized: spheroids, discoids, blades and rods (Fig. 1). Where three dimensions of the particles are known, correlated with three main axes, notably long axis - length *a*, moderate length axis - width *b*, short axis - thickness *c*, and using the quotient of b/a and c/b of these axes, the shapes mentioned are defined in the following way: discoid (b/a>2/3 and c/b<2/3), spheroid (b/a>2/3 and c/b>2/3), blade (b/a<2/3 and c/b<2/3), rod (b/a<2/3 and c/b>2/3).

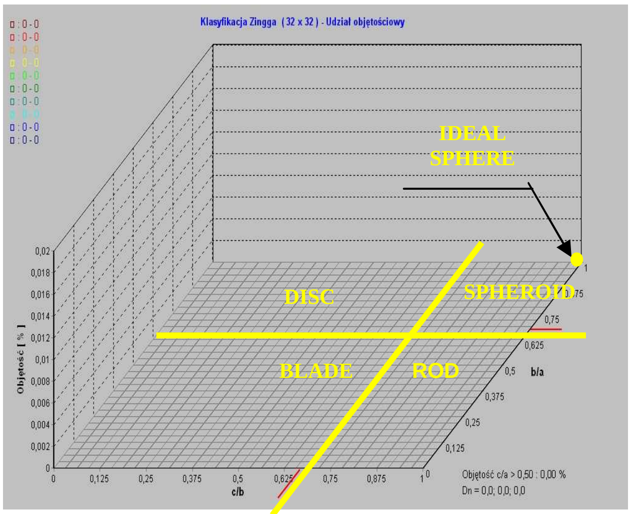


Fig. 1 Diagram showing Zingg shape classification

The shapes so defined occupy separate fields on the diagram. Other terms in literature are also used for determining the particles shape of, e.g. ellipsoid-shaped, very elongate-shaped, disc-shaped (Gradziński et al., 1986).

The size of grains for which the measurements of their shapes are performed depends on the fractions found in the natural material tested or any other material we wish to use for practical purposes. The fractions (grains size) should be representative for the material tested. The best solution is to determine the grains size and particles shape of all fractions found in the material tested. The grain size of various materials most frequently fluctuates within the interval from fractions of millimetre to several dozen cm.

The measurements and analysis of the grains size and particles shape is very essential for science and research, e.g. in geology for the analysis of genesis and processes of variable clastic deposits. Also, these types of measurements are of big significance in practice, e.g. in soil mechanics they allow to help in the evaluation of the impact of the grains size and particles shape on the physical and mechanical properties of geomaterials.

2. METHODS OF RAPID 3D GRAINS MEASUREMENT

The 3D picture may be obtained by means of the optical field 3D scanner. The complicated system uses data from the scanner in the form of clouds of points, which, by means of complex algorithms, need to be processed. This processing, spread into few phases, is unsuitable for the online measurement for rapid evaluation of the grains distribution shape. The problem preventing the dissemination of the above mentioned method of testing has always involved the quick and automatic 3D measurement of the particles shape. Such measurements may be performed with the use of various methods, e.g. using two cameras to take pictures or scanning the grains with the use of two optical electronic converters. Where the cameras are used for measurements, the complicated analyzes of two sequences of grains pictures being moved, which must be properly placed towards the camera lens, are made. This method is expensive, difficult in common application and inefficient.

The method of falling grain scanning is much more convenient and is used in the optical electronic analyzers, e.g. AWK 3D (Fig. 2).

Fig. 2 AWK 3D analyzer

In these types of analyzers, two dimensions are obtained owing to the measurements performed by the converters, while the third dimension is determined on the grounds of the number of scanning processes. The direction and method of fall-down is controlled by the dedicated, special shaped channel along which the grains are transmitted from the vessel to the measuring space. Big frequency of scanning, in the order of 500 kHz and 12-bit resolution of measurements, ensures that this measuring method is accurate.

On the grounds of the dimensions of grains measured, they may be segregated according to the dimension intervals (classes), in accordance with the sieve analysis. In addition, the measurements performed allow all quantitative-dimensional analyzes.

3. DESCRIPTION OF MEASURING METHOD

The AWK 3D houses the optic plane (measurement space), common for both identical optical converters arranged perpendicular to one another (Fig. 3). Using such converters, the sequence of results may be obtained, describing the surface profiles of the grain being moved from two directions and the identical length of these profiles in the third direction.

The optical converter (Fig. 3) comprises the radiation unit [1] lighting the optical system [2], which forms the parallel beam of radiation [3] with thickness of several hundred µm. The optical system [4] focuses the bundle radiation [3] on the photo sensor [5]. The measuring space is found between the optical system [2] and [4]. Where the grain falls down through the measuring space, it causes the radiation to be dispersed, triggering the change to the current flowing through the photo sensor. The change in question will be proportional to the dimensions of the element falling down.

Three dimensions of each grain are recorded in the matrix, e.g. 126^3, which is equal to more than 2 million of dimensions combinations. In addition, the profile of each grain is analyzed in real time, which provides the precise information about the volume and shape of the grain.

The measuring surface of the AWK 3D analyzer may be arbitrarily large. Due to practical purposes, it is, however, limited to the dimensions of 40x40 mm, allowing measuring the grains with maximum size about 30 mm.

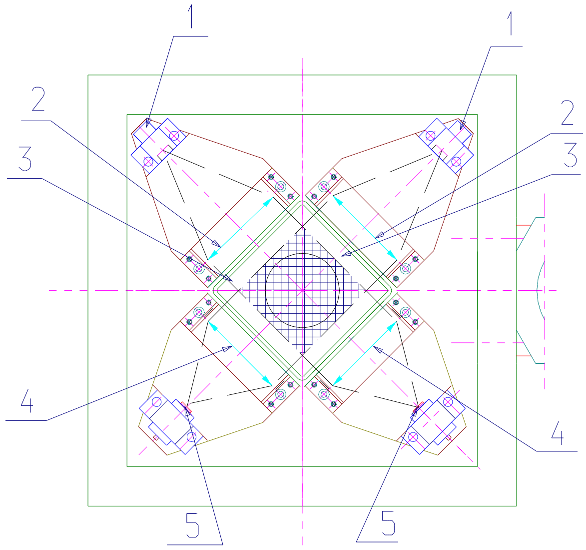


Fig. 3 AWK 3D measuring probe (description of designations provided in the text)

The dozing unit with the tilted and vibration channel has been developed to allow smooth measurements of a number of grains. The channel stabilizes the grains fall-down through the measuring space. The frequency and amplitude of channel vibration is controlled by the dedicated software. The value of these parameters depends on the number of grains falling down and measured in the measuring space in the unit of time, i.e. measuring rate. Where the measuring rate increases, the frequency and amplitude of channel vibrations reduce. The number of grains falling down reduces and the measurement rate is automatically lowered. Coupling the amplitude and frequency of channel vibrations with the measurement rate serves equalling the number

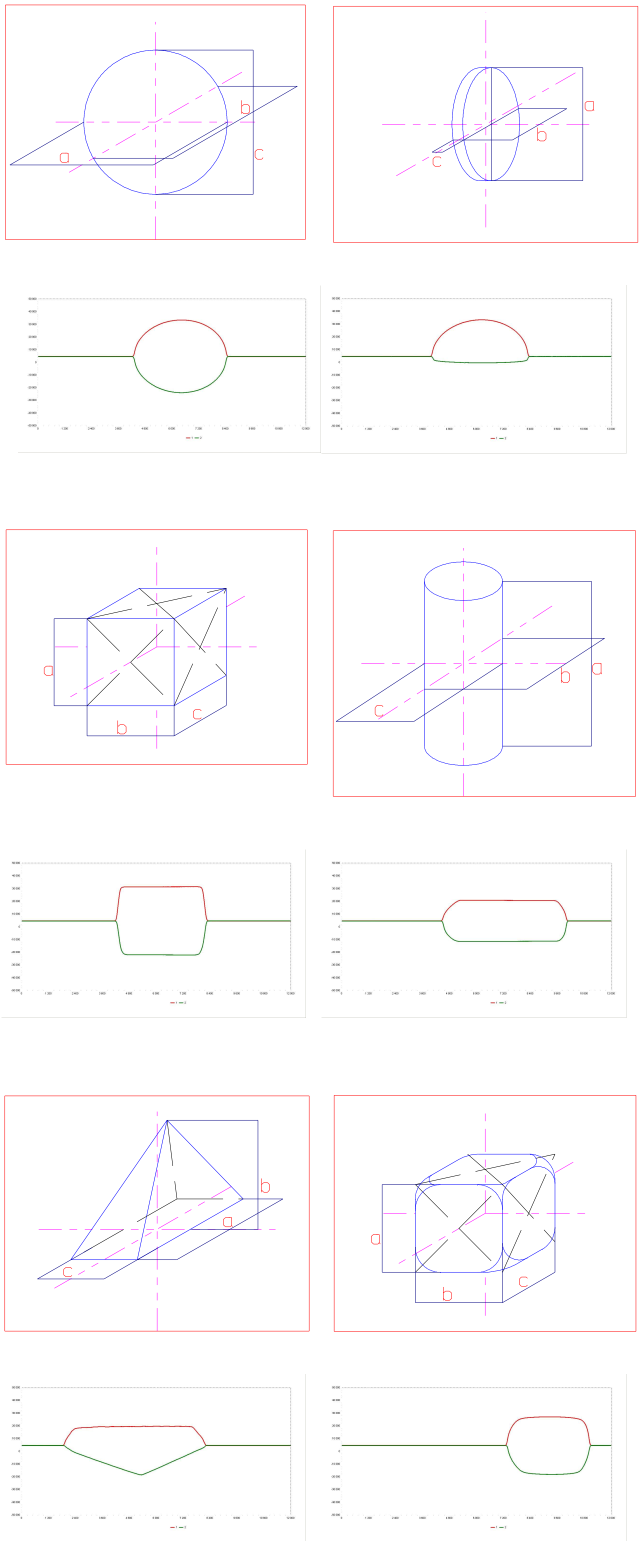


Fig. 4 The shape of specimens scanned and saved in the computer

of grains falling down through the measuring space to the value allowing avoiding the coincidence of grains in the course of measurements.

Fig. 4 shows a few selected examples of shape specimens scanned, according to which the correctness of the AWK 3D analyzer performance is checked. Each grain may be identified according to the shape and dimensions which are saved in the computer memory. For the purposes of particularly accurate analyzes, the entire measuring process may be saved on the computer's HDD to allow multiple playback for analyzing the geometry of grains in many ways. The data for such analysis are presented in the Fig. 5.

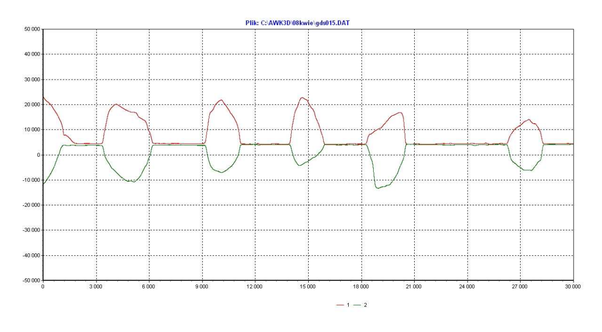


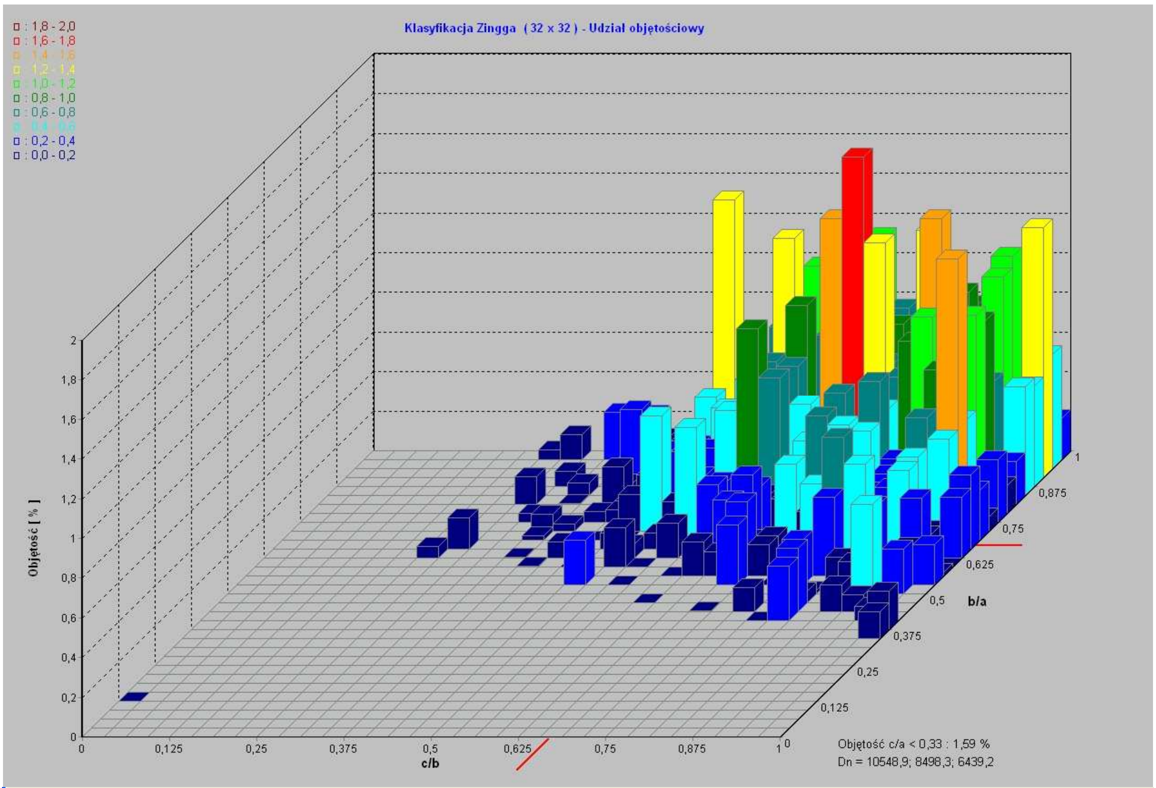
Fig. 5 Recording of the scanned shape of tested grains

4. RESULTS OF TEST

In order to perform the typical analysis, made with accuracy of ±1%, 2-million to matrix of shapes of grains shapes will be sufficient. Any number of grains may be recorded in any place of the matrix, following which, on the grounds of matrix coordinates, the year volume, shape and share by volume may be calculated in the total distribution of grains measured. For the purposes of assessing the particles shape, Zingg shape classification has been employed, with the results of measurements presented in the Fig. 6. Tabulated results are presented under the chart, where the percentage of volume of grains with various shapes, total volume of particles with the shape of spheroids, discoids, blades and rods is provided (compare with Fig. 1). In addition, the percentage content of the irregular particles is calculated, as is the case for the Szulc slide caliper.

The results of measurements are accompanied by the sieve analysis, calculated according to the ELSIEVE method simulating the results of measurements according to the mechanical sieves (Kamiński and Kamińska, 2007; Kamiński and Trzciński, 2008 – in print).

The AWK 3D analyzer described above, performing measurements within the range of



Zingg classification - Volume [%]

b/a \ c/b	0,0–0,1	0,1–0,2	0,2–0,3	0,3–0,4	0,4–0,5	0,5–0,6	0,6–0,7	0,7–0,8	0,8–0,9	0,9–1,0
0,9–1,0	–	–	0,18	0,34	0,75	4,07	6,17	5,05	6,18	6,40
0,8–0,9	–	–	0,14	0,14	1,32	2,20	4,71	7,96	7,35	7,45
0,7–0,8	–	–	–	0,19	0,40	3,20	3,55	4,03	6,12	5,61
0,6–0,7	–	–	0,22	0,00	0,16	0,55	1,28	1,19	3,19	3,74
0,5–0,6	–	–	–	0,01	0,23	0,00	0,29	1,07	0,80	1,88
0,4–0,5	–	–	–	–	–	–	0,00	0,13	0,79	0,65
0,3–0,4	–	–	–	–	–	–	–	–	–	0,33
0,2–0,3	–	–	–	–	–	–	–	–	–	–
0,1–0,2	0,00	–	–	–	–	–	–	–	–	–
0,0–0,1	–	–	–	–	–	–	–	–	–	–

Shapes' distribution : b/a = 0,67 : c/b = 0,67 Volume c/a < 0,33 1,59 %

Shape	Percent
Sphere	63,72
Discus	23,48
Cylinder	11,21
Blade	1,59

Distribution on sieves - Volume [%]

	0	2000	4000	6300	8000	9500	12500	16000	20000
D	100,00	99,92	99,48	94,85	67,53	35,94	6,28	2,04	0,00

Fig. 6 Results of measurements according to Zingg analysis, Szulc slide caliper (Volume = 1,59%) and ELSIEVE sieve analysis

grain sizes from 0.05 to 30 mm, may, due to its accuracy and universalism, be the appliance used by specialists of various scientific disciplines and may be applied for a number of practical applications.

Currently, such instrument is successfully used at the laboratory of the Institute of Hydrology and Engineering Geology of the Faculty of Geology at University of Warsaw (Gotowiec, 2006; Jagliński, 2006).

5. SUMMARY

The measurements of the grains size and particles shape are extremely useful in scientific research and for practical purposes. The Zingg classification, allowing performing the analysis of the particles shape, is the most useful tool. The measurement methods applied to date have been very time and labour consuming and their accuracy is insufficient. In order to speed up and achieve bigger accuracy of such measurements, the automatic measurement with the use of optical electronic analyzers, e.g. AWK 3D analyzer, may successfully be applied. Such analyzers allow the determination of the size and shape of three-dimensional grains and obtaining a number of additional parameters characterizing the features of grains size distribution of various geomaterials. The instruments of this type are applied at a number of laboratories in Poland, including the laboratory of the Institute of Hydrology and Engineering Geology of the Faculty of Geology at University of Warsaw.

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