ANALYSIS OF SIZE AND SHAPE OF ABRASIVE MICROGRAINS IN LAPPING OF ASSEMBLY JOINTS

Analiza rozmiarów i kształtu mikroziarn ściernych w docieraniu połączeń montażowych

Анализ размеров и формы абразивных микро зерн в притирке сборочных соединений

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A b s t r a c t: In the paper, automated analysis of size and shape of abrasive micrograins was presented. In the tests of the micrograins of boron carbide, silicon carbide and electrocorundium, the stereoscopic microscopy and the specialized software MultiScan v.6.08 were applied.

K e y w o r d s : abrasive micrograins, size, shape, measurements

S t r e s z c z e n i e: W pracy przedstawiono skomputeryzowaną analizę wielkości i kształtu mikroziaren ściernych. W badaniach mikroziaren weglika boru, weglika krzemu i elektrokorundu zastosowano mikroskopię optyczną oraz specjalistyczne oprogramowanie MultiScan v. 6.08.

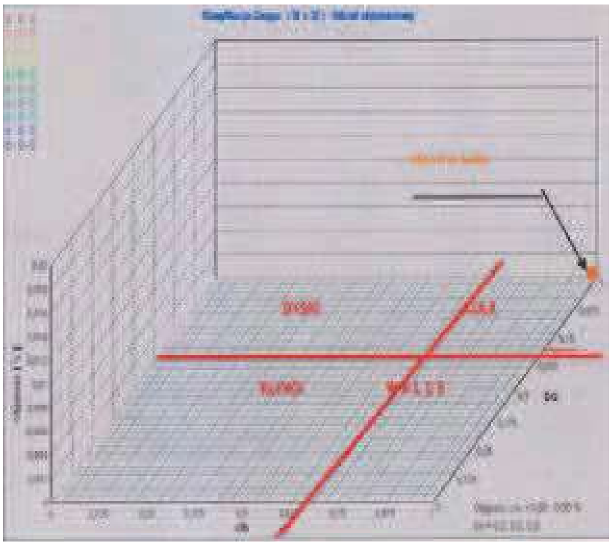
S ł o w a k l u c z o w e : mikroziarna ścierne, wielkość, kształt, pomiary

Introduction

One of the methods for machining, employed in assembly technologies, is lapping of the surface of componential elements with a loose abrasive. The aim may concern obtaining a required dimension of technological compensator, or individual fitting of immobile or mobile joints. The run and the results of lapping are affected by many kinetic, technological and material factors. The quality of lapping factor is one of the major parameters; it concerns mainly the stereometry, applied in the lapping suspension or paste of micrograins [2]. At present, there are many types of abrasive pastes, offered by trade, both traditional as well as diamond ones which may be utilized in shaping the assembly joints [1]. Due to the chemical components, the time of utilization of abrasive pastes is limited. Therefore, in practice and especially in the case when there is a need of the small portions of the pastes, being often differentiated in respect of the type of abrasive and size of micrograins, the specified batches of the pastes are prepared directly before their use in the lapping process. The mentioned situation may have also place in the case of assembling a prototype or during the experimental tests. Lapping may be performed irrespectively of the type of materials of the componential elements. Ensuring the specified requirements in respect of the state of the shaped joints requires control of the size of abrasive before the preparation of the paste.

Zingerra classification [6] is often used in analysis of the shape of the micrograins. It distinguishes four basic forms: discs (b/α >2/3), balls, blades (b/α <2/3 and c/b <2/3) and rollers (b/ α <2/3 and c/b >2/3) (Fig.1) where the dimensions of the grains, occurring in the space are: α – length; b – width; c – height, respectively (dimensions are correlated in the system of three main axes: long, medium and short). According to FEPA standard 42-D—1984 (Federation of the European producers of Abrasives) [17] it is also possible to use the mean size of the micrograin (Tab. 1).

Fig. 1. Zingga diagram [6]
Rys. 1. Diagram Zingga [6]



Tab. 1. Size of abrasive micrograins by FEPA [17]
Tab. 1. Wielkości mikroziaren ściernych wg FEPA [17]

Marking of abrasive micograins	Mean size [µm]
F230	56.0 – 50.0
F240	46.5 – 42.5
F280	38.5 – 35.0
F320	30.7 – 27.7
F360	24.3 – 21.3
F400	18.3 – 16.3
F500	13.8 – 11.8
F600	10.3 – 8.3
F800	7.5 – 5.5
F1000	5.3 – 3.7
F1200	3.5 – 2.5

During the lapping process, the individual abrasive micrograins change not only the shape but also the size. The mentioned transformations [10] describe their shape (approximation of the shape to ellipse) (Fig.2), distribution of the size (circle inscribed in a single grain) (Fig.3) and the so-called "sharpness" SV (on the basis of Richardson technique) (Fig.4). In case of approximation of the grain shape to ellipse, we may distinguish as follows: coefficient of proportion AS = a/b, coefficient of elongation EL = log2 (a/b) and coefficient of dispersion DP = log2 (πab).

In the lapping process, the change in distribution of the size of micrograins in the zone of treatment has place (Fig.5), so the working slot is decreased and changes the load of individual grain. In the case of periodical dosage (supplementation) of abrasive paste, the process of lapping may be intensified. A single dosage of lapping agent enables, however, obtaining of lower values of coarseness parameters of the shaped surfaces.

In practice, there are few methods for evaluation of the size and shape of micrograins applied, mainly the sedimentation, microscopic and laser methods [4, 5, 7, 8, 11, 15, 16]. Segregation according to the size may be performed via the stream of swirling or direction-changing air, separation as a result of washing out with water, by gravitational sedimentation or by centrifugal force. For analysis of the degree of wear of the grains, optical and scanning microscopy, roentgen and laser analysis may be utilized. In the case of the size of micrograins, optical-electronic microscopes (e.g. 2DiSA by Kamika) [14] or laser microscopes (e.g. Analysette 22 nano Tec by Fritsch company) are very useful. In the discussed below studies, the computerized stereoscopic microscopy was employed [9].

Fig. 2. Definition of the shape of abrasive micrograins [10]
Rys. 2. Określenie kształtu mikroziarna ściernego [10]

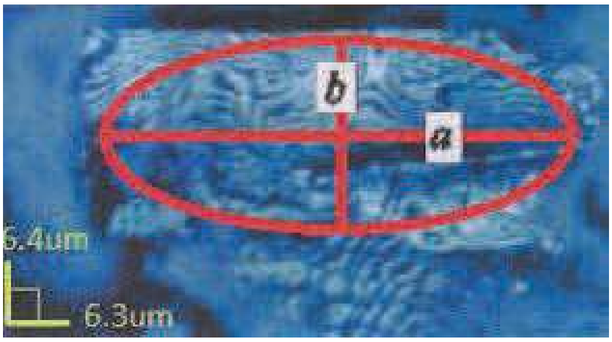


Fig. 3. Definition of the size of abrasive micrograins [10]
Rys.3. Określenia wielkości mikroziarna ściernego [10]

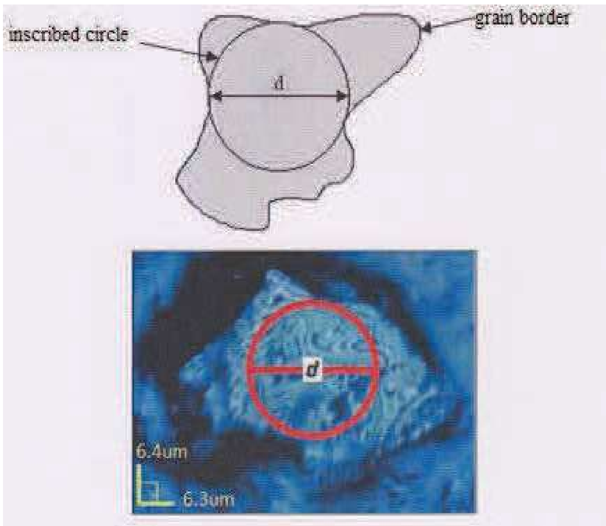


Fig. 4. "Sharpness" of abrasive micrograins (β>a, SV=cos β/2) [10]
Rys. 4. "Ostrość" mikroziarna ściernego (β > α, SV = cos β/2) [10]

Measurement test stand and methodology of the studies

For measurements of the size and shape of the abrasive micrograins, the setup equipped in stereoscopic microscope, CCD camera and software MultiScan n.6.08 (Fig. 6) was used. Before analysis of the micrograins, scattered on the white surface, it is necessary to perform a precise regulation of the exposition, depth of colour and contrast in the window of Camera - HB Series twain

Fig. 5. Probability distribution P(d) of abrasive micrograin size d at different lapping time (after t = 15 sec. - analysis 62 micrograins, after t = 90 sec. - 90 micrograins, after t = 180 sec. - 100 micrograins, after t = 250 sec. - 100 micrograins) [3]
Rys. 5. Rozkład prawdopodobieństwa P(d) wielkości mikroziarna ściernego d w czasie docierania (po t = 15 sekundach analizowano 62 mikroziarna, po t = 90 - 101 mikroziaren, po t = 180 - 100 mikroziaren, po t = 250 - 100 mikroziaren) [3]

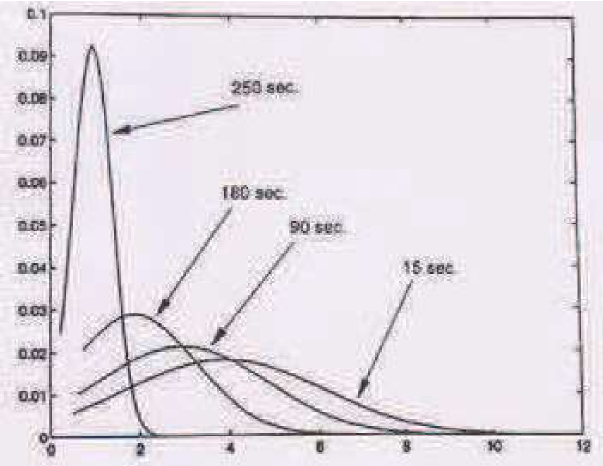
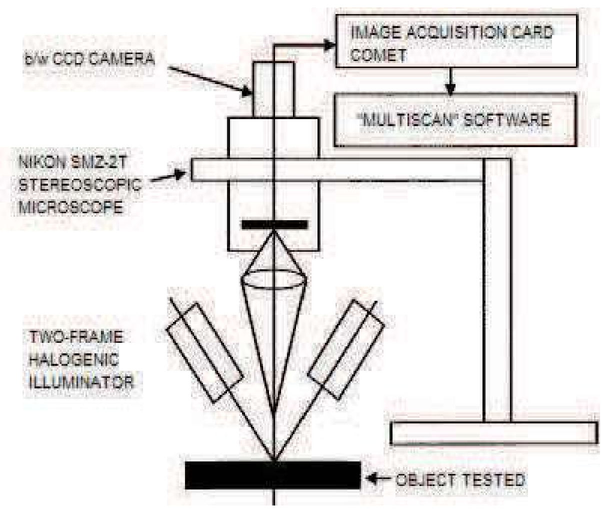


Fig. 6. Scheme of measurement stand and software used
Rys. 6. Schemat stanowiska pomiarowego i okno programu

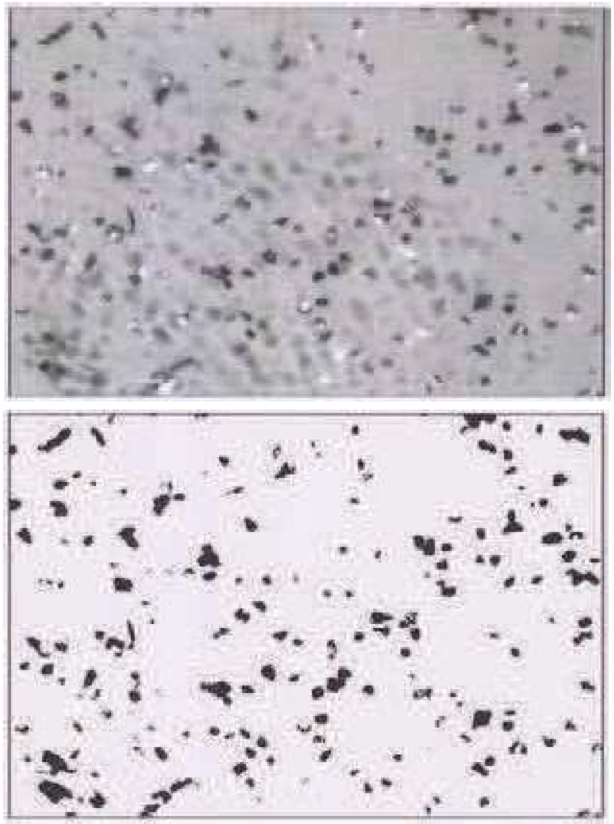
a)



b)

and adapt the light to the conditions of the environment (existing in a room), fix the magnification of the image and regulate its sharpness [12]. The image of the analyzed batch of the abrasive micrograins is saved in a form of BMP file, with the application of binarizing filters which enable removal of the shade of background and a degree of grey colour of the particular grains (Fig. 7).

Fig. 7. View on abrasive micrograins (95A F 500): a) before filtration, b) after filtration
Rys. 7. Widok mikroziaren elektrokorundu (95A F500): a) przed filtracją, b) po filtracji



During the first filtration stage, the image is obtained in which the grains adopt black colour on a white background, however in the particular examined objects there also visible white fields being the residues of light reflexes coming from the primary microscopic image (Fig. 8). The removal of the mentioned reflexes occurs by the so-called "filling the openings", using negative and binarization. Calibration of stereoscopic microscope (pattern of 1-mm segment was divided into 100 parts) was carried out with the 6-fold magnification, identical as during the measurements of the particular grains.

Minimum size of the examined batches $n = z_a^2\sigma^2/e^2$ was determined for confidence interval $1-a = 0.9$ at multiple of standard error of mean for $z_a = 1.96$ and the assumed maximum error $e = 0.1$. Standard Deviation σ was determined in a preliminary test. The maximum

Fig. 8. Images of abrasive micrograins: a) before modification, b) after filtration
Rys. 8. Obrazy ziaren ściernych: a) przed modyfikacją, b) po filtrowaniu

a) b)

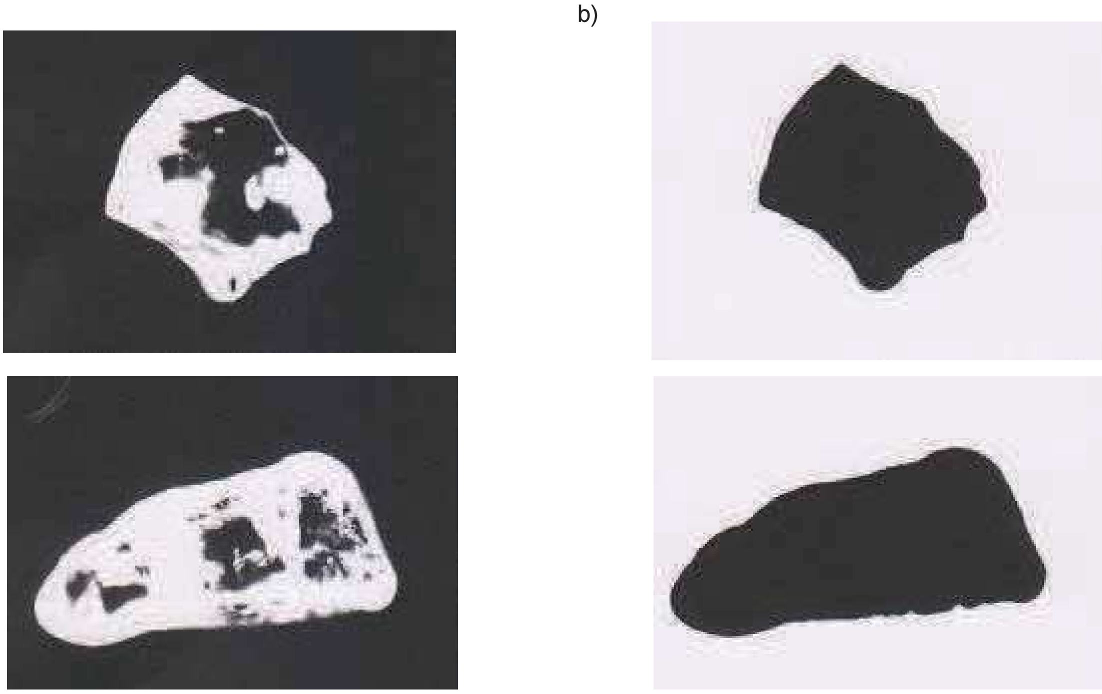
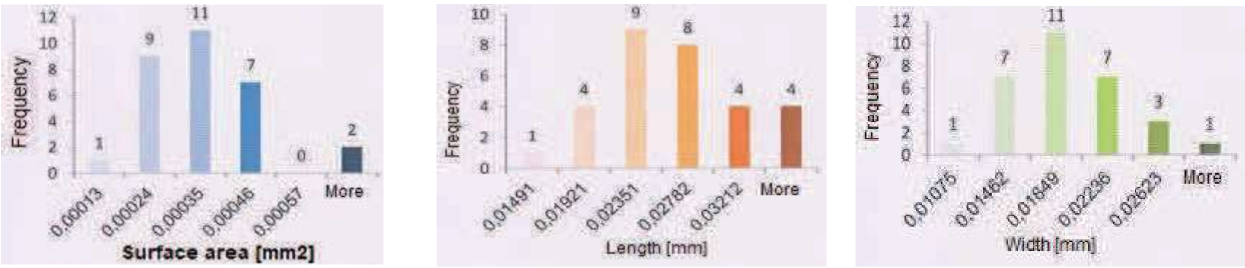


Fig. 9. Measurements of abrasive micrograins 95A F 500: a) distribution of area A, b) distribution of length l, c) distribution of width s
Rys. 9. Pomiary mikroziaren 95A F500: a) rozkład pola powierzchni A, b) rozkład długości l, c) rozkład szerokości s

a) b) c)

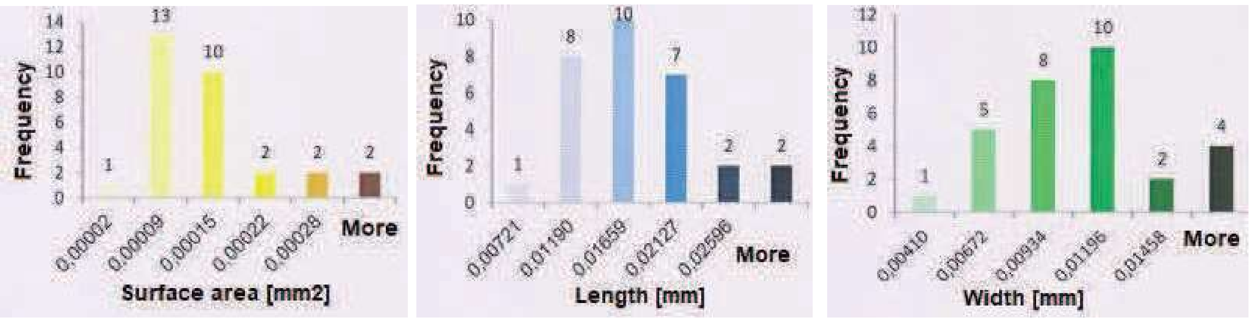


Tab. 2. Characteristics of distributions of abrasive micrograins 95A F 500
Tab. 2. Charakterystyki rozkładów mikroziaren 95A F500

	Surface area *A* [mm^2]	Length *l* [mm]	Width *s* [mm]
Arithmetical mean	0,00031	0,02448	0,01758
Standard error	0,00002	0,00100	0,00078
Median	0,00027	0,02374	0,01716
Range	0,00056	0,02038	0,01935
Standard Deviation	0,00013	0,00550	0,00427
Variance	0,00001	0,00003	0,00002
Kurtosis	2,38359	-0,42332	1,01901
Skewness	1,42563	0,49578	0,83003

Fig. 10. Measurements of abrasive micrograins BC F 600: a) distribution of area A, b) distribution of length l, c) distribution of width s
Rys. 10. Pomiary mikroziaren BC F600: a) rozkład pola powierzchni A, b) rozkład długości l, c) rozkład szerokości s

a) b) c)

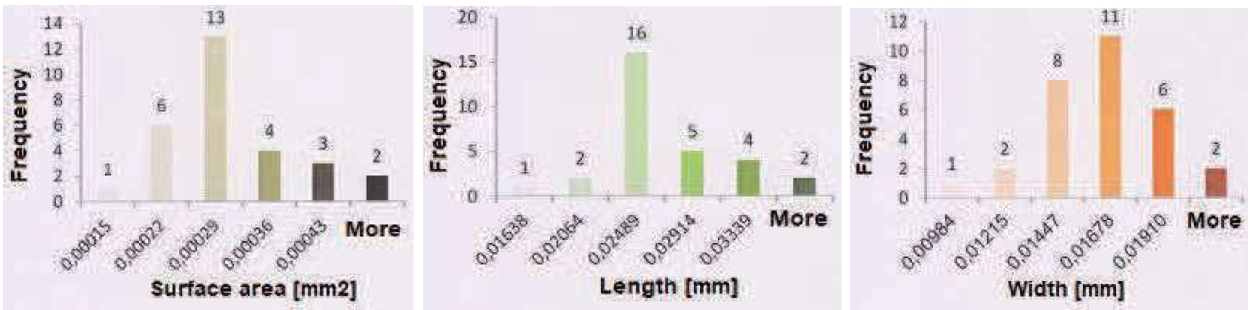


Tab.3. Characteristics of distributions of abrasive micrograins BC F 600
Tab. 3. Charakterystyki rozkładów mikroziaren BC F600

	Surface area *A* [mm^2]	**Length *l* [mm]**	**Width *s* [mm]**
Arithmetical mean	0,00012	0,01502	0,00965
Standard error	0,00001	0,00099	0,00065
Median	0,00010	0,01471	0,00950
Range	0,00032	0,02344	0,01309
Standard Deviation	0,00008	0,00542	0,00356
Variance	0,00001	0,00003	0,00001
Kurtosis	2,44899	1,71377	-0,14006
Skewness	1,57688	1,14321	0,47499

Fig. 11. Measurements of abrasive micrograins 98 C F 500: a) distribution of area A, b) distribution of length l, c) distribution of width s
Rys. 11. Pomiary mikroziaren 98C F500: a) rozkład pola powierzchni A, b) rozkład długości l, c) rozkład szerokości s

a) b) c)



dimensions of the images of abrasive micrograins in space of observations were determined, measuring their length l and width s and surface area A.

The results of the studies

The conducted experiments included tests of common electrocorundium 95 A (30 micrograins were measured) with a normative (specified in sedimentation analysis) dimensions F 500, black silicon carbide 98 C F 500 (30 micrograins) and boron carbide BC F 600 (21 micrograins). Fig.9-11 contain the obtained histograms of the micrograins' dimensions whereas Tables 2-4 give their basic characteristics.

The constructed distributive series of the examined geometrical parameters of the micrograins differ inconsiderably each other. For example, in the case of boron carbide micrograins, the distributions of the surface area A and of length l reveal a positive asymmetry (right

Tab. 4. Characteristics of distributions of abrasive micrograins 98 C F 500
Tab. 4. Charakterystyki rozkładów mikroziaren 98C F500

	Surface area *A* [mm^2]	Length *l* [mm]	Width *s* [mm]
Arithmetical mean	0,00029	0,03931	0,01553
Standard error	0,00002	0,00346	0,00047
Median	0,00027	0,03133	0,01537
Range	0,00037	0,06491	0,01157
Standard Deviation	0,00010	0,01897	0,00255
Variance	0,00001	0,00036	0,00001
Kurtosis	0,68596	-0,36061	0,18764
Skewness	0,97009	0,89248	0,12248

Tab. 5. Analysis of the shape of abrasive micrograins 95A F 500
Tab. 5. Analiza kształtu mikroziaren 95A F500

No.	Length *l* [mm]	Width *s* [mm]	Coefficient of proportion $AS = l/s$	Coefficient of elongation $EL = log_2(l/s)$	Coefficient of variation $DP = log_2(\pi ls)$
1	0,023	0,019	1,20	0,26	-9,45
2	0,019	0,012	1,58	0,66	-10,47
3	0,015	0,011	1,39	0,47	-10.96
4	0,029	0,024	1,20	0,26	-8,87
5	0,025	0,018	1,40	0,49	-9,44
6	0,017	0,014	1,17	0,22	-10,35
7	0,029	0,018	1,61	0,69	-9,20
8	0,032	0,023	1,38	0,47	-8,76
9	0,021	0,015	1,39	0,48	-9,98
10	0,036	0,022	1,64	0,71	-8,62
11	0,020	0,016	1,26	0,34	-9,95
12	0,019	0,018	1,05	0,07	-9,91
13	0,027	0,021	1,25	0,32	-9,14
14	0,024	0,019	1,25	0,33	-9,48
15	0,023	0,014	1,61	0,68	-9,95
16	0,020	0,012	1,72	0,78	-10,39
17	0,035	0,030	1,17	0,23	-8,23
18	0,018	0,013	1,38	0,46	-10,34
19	0,026	0,021	1,22	0,29	-9,18
20	0,024	0,020	1,17	0,22	-9,35
21	0,021	0,019	1,09	0,12	-9,63
22	0,025	0,014	1,82	0,87	-9,84
23	0,024	0,016	1,55	0,63	-9,69
24	0,026	0,015	1,72	0,78	-9,65
25	0,032	0,023	1,41	0,49	-8,76
26	0,022	0,014	1,53	0,61	-9,95
27	0,029	0,015	1,98	0,99	-9,51
28	0,020	0,017	1,16	0,21	-9,83
29	0,032	0,017	1,90	0,92	-9,19
30	0,020	0,015	1,33	0,41	-10,10
Mean			**1,42**	**0,48**	**-9,61**

side) while in the case of width s of the microscopic images of the micrograins, there is a lack of such asymmetry what means greater dispersion of the results. In the measurements of silicon carbide micrograins, the obtained distributions are approximate to a normal one; the results are focused around the mean value and the coefficients of skewness are near to one – what is an evidence of a lack of asymmetry of distributions. When comparing the parameters of the shape of the micrograins of electrocorundium 95 A and of silicon carbide 98 C, with the same normative number F 500 (Tab. 5 and 6), it is easy to notice that the mean coefficient of proportion AS and the coefficient of elongation EL is higher for the grains of silicon carbide. It means that the mentioned grains have more elongated shape. The negative values of the variability coefficient DP indicate a big dispersion of the results of the measurements of the grains, both of the length l and of the width s. It may be, however, generally stated that the examined micrograins of electrocorundium and silicon carbide do not reveal any significant differences in respect of their shape. Due to the small differences in the examined geometrical parameters and time consumption of the evaluation in the conducted analysis, it was adopted that the length of the image l ≈a and the measured width s ≈ b (Fig. 2).

Summary

When conducting the microscopic measurements of the dimensions of abrasive micrograins, the attention should be paid to the following facts:

- The abrasive micrograins cannot be damp or glued together,

Tab. 6. Analysis of the shape of abrasive micrograins 98 C F500
Tab. 6. Analiza kształtu mikroziaren 98C F500

No.	Length *l* [mm]	Width *s* [mm]	Coefficient of proportion $AS = l/s$	Coefficient of elongation $EL = log_2(l/s)$	Coefficient of variation $DP = log_2(\pi ls)$
1	0,016	0,012	1,33	0,42	-10,70
2	0,017	0.011	1,55	0,63	-10,73
3	0,016	0,013	1,23	0,30	-10,58
4	0,021	0,010	2,10	1,07	-10,57
5	0,019	0,014	1,36	0,44	-10,23
6	0,023	0,014	1,64	0,72	-9,95
7	0,021	0,014	1,50	0,58	-10,08
8	0,026	0,012	2,17	1,12	-10,00
9	0,022	0,015	1,47	0,55	-9,91
10	0,023	0,015	1,53	0,62	-9,85
11	0,024	0,015	1,60	0,68	-9,79
12	0,021	0,013	1,62	0,69	-10,19
13	0,026	0,013	2,00	1,00	-9,88
14	0,021	0,016	1,31	0,39	-9,89
15	0,024	0,014	1,71	0,78	-9,89
16	0,021	0,017	1,24	0,30	-9,80
17	0,023	0,016	1,44	0,52	-9,76
18	0,022	0,016	1,38	0,46	-9,82
19	0,023	0,016	1,44	0,52	-9,76
20	0,022	0,019	1,16	0,21	-9,57
21	0,031	0,016	1,94	0,95	-9,33
22	0,023	0,019	1,21	0,28	-9,51
23	0,031	0,014	2,21	1,15	-9,52
24	0,026	0,016	1,63	0,70	-9,58
25	0,027	0,020	1,35	0,43	-9,20
26	0,031	0,016	1,94	0,95	-9,33
27	0,028	0,019	1,47	0,56	-9,23
28	0,030	0,021	1,43	0,51	-8,98
29	0,035	0,018	1,94	0,96	-8,98
30	0,038	0,017	2,24	1,16	-8,95
Mean			**1,60**	**0,66**	**-9,78**

- The external light cannot cause the occurrence of numerous shadows of the examined objects,
- In the case of occurrence of the light reflexes of the micrograins which have not been removed in the stage of image filtration, they should be omitted in the analysis,
- The distribution of the micrograins on the white surface should be sufficiently dispersed,
- Light scanning microscopy should not be used to very fine micrograins (with normative number F 1200 and smaller).

In spite of the above mentioned limitation, utilization of computerized microscopic methods in the evaluation of the size and shape of the abrasive micrograins in the procedures of assembly lapping may be technologically effective and economically justified.

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