Łukasz GIERZ, Jarosław SELECH, Konrad WŁODARCZYK
Politechnika Poznańska, Instytut Maszyn Roboczych i Pojazdów Samochodowych
ul. Piotrowo 3, 60-965 Poznań, Poland
e-mail: lukasz.gierz@put.poznan.pl

EVALUATION OF THE SHAPE AND DIMENSIONS OF CEREAL SEEDS AND OTHER CROPS FOR MODELING SOWING AND SEED SEPARATION

Summary

The paper presents the results of laboratory tests on the shape and dimensions of cereal seeds and other crop plants necessary for modeling the sowing and separation of these seeds. Individual grains are not usually identical, so their linear dimensions are not uniform in different directions. The ability to determine the shape and dimensions of grains is extremely important from the point of view of basic research as well as in practice as a boundary condition for machine design. During the study a photogrammetric method was used based on the "Gabar" program written at Poznan University of Technology. It allows us to significantly improve and speed up the process of obtaining data with sufficient accuracy and can be applied to the overall assessment of other raw materials such as those from recycling.
***Key words**: grain dimensions, image binarization, contour extraction, photogrammetric measurements*

OCENA KSZTAŁTU I WYMIARÓW NASION ZBÓŻ I INNYCH ROŚLIN UPRAWNYCH NA POTRZEBY MODELOWANIA PROCESU WYSIEWU I SEPARACJI NASION

Streszczenie

W pracy przedstawiono wyniki badań laboratoryjnych kształtu i wymiarów nasion zbóż i innych roślin uprawnych niezbędnych do modelowania procesu wysiewu i separacji tych nasion. Poszczególne ziarna nie są zazwyczaj identyczne, a więc ich wymiary liniowe nie są jednakowe w różnych kierunkach. Możliwość określenia kształtu i wymiarów ziaren jest niezwykle istotna z punktu widzenia badań podstawowych, jak również w praktyce jako warunki brzegowe do projektowania maszyn. Podczas badań wykorzystana została metoda fotogrametryczna bazująca na napisanym w Politechnice Poznańskiej programie „Gabar". Pozwala ona znacznie usprawnić i przyspieszyć proces pozyskiwania danych z wystarczającą dokładnością, jak również może być zastosowana do oceny gabarytowej innych surowców np. recyklingowych.
***Słowa kluczowe**: wymiary ziarna, binaryzacja obrazu, wyodrębnianie konturów, pomiary fotogrametryczne*

1. Introduction

Most of the cultivated crops are now sown by means of row drills, universal ones working alone or more often as components of agronomic and sowing aggregates [10] and non-ornamental tillage and sowing [17]. Cereal aggregates can be both row and spot drills. The most commonly sown crops are: wheat, rye, triticale, barley oats, oilseed rape, lupine, pea, etc. Some of the seedlings previously sown by means of row drills are now sown with precise seeders [9], mainly beets and maize. Working units of the seed drill and other machines such as the cleaner, crusher or grinder must be adapted to the size and shape of the seed.

Considering the sowing process, density (distribution) and depth of seed are also important. Hence knowledge of the geometric parameters of the kernel plays a fundamental role in the construction of not only seeders but any other machine in which there is a grain flow, e.g. harvesters, cleaning and sorting machines, shredders, crushers, dryers, grain conveyors and other materials such as alternative fuels etc. Learning about the geometrical features of kernels is of interest not only to agricultural machine designers but also to machine builders for the food industry. The problem of evaluating the geometrical properties of the raw material is also apparent in the mining, extraction and wood industries, where we deal with various fractions of gravel, aggregate, wood waste, etc. For the design of machines and models of heat and mass exchange, mathematical models of materials are very helpful. They are intended [1, 2, 3]. In order to correctly develop mathematical models, the actual geometrical dimensions of the seeds or other agricultural or industrial raw materials should be precisely determined. The presentation of lumps of grain, agricultural raw materials or industrial discrete material is of great importance in the design of work processes [16]. Mathematical models describing the shape of the seeds, agricultural and industrial raw materials are helpful in determining regulatory parameters for agricultural machinery and equipment and food processing [15].

Measurement of the dimensions and shape of the grain for machine construction has been going on for a very long time. Previously used measurement methods with classical linear measuring tools were relatively inefficient, and the results of old measurements may not meet current needs due to genetic changes that occur in cultivated plant varieties over time and progress in new cultures. On the other hand, methods of calculating and simulating processes occurring in machines, including seed sowing processes, require more precise geometric models of seed. An example is the DEM method that requires precise modeling of the seed shape. There is therefore a need to continually supplement the databases of seed size and shape collected so far.

2. Current state of knowledge

Due to work on the modeling of threshing, sorting and sowing processes and pneumatic transport, task has been carried out in this area for many years [2, 3, 9, 10, 11]. For these needs, their own software has been developed for photogrammetric seed measurement and the design of their 3D models in the form of meshes approximating the outer shape on the basis of a series of photographs. Exact photos of the group of seeds spread out on the illuminated back of the table are binarized and then subject to segmentation and geometric calculations, which consist in determining the dimensions of the grain contours of moments of inertia of the grain silhouette, etc. The results of these measurements were statistically processed, i.e. calculations of distribution parameters of geometric features. Similar work is being done at the University of Life Sciences in Poznan and computer software for FEM modeling is being developed [19, 21]. This paper presents a computer program for the generation of FEM meshes based on a series of photographs of the cross sections of microtome obtained [20]. The program has a wealth of photo opportunities for realistic imaging of the grain model.

3. Aim of the study

The aim of the study was to supplement the set of data on the geometrical features of cereal and cereal grain crops for the purposes of the design of agricultural and working machines for sowing, threshing, cleaning, grinding of kernels as well as industrial crushing and screening machines. The scope of work included measuring basic grain *dimensions* (length, width). Based on the data obtained, the shape factor and surface area were also calculated. Three samples of seeds were weighed before each measurement - each sample consisted of 10 seeds - to determine the mass of one thousand seeds and the length, width and thickness of the seedlings measured with a caliper.

4. Research subject

The following grains were the research object: rye (variety: Dańkowskie zlote), winter wheat (Tulsa variety), winter barley (Titus variety), winter triticale (Borwo variety), oats (variety: Bingo), corn (Celux variety) Winter oilseed rape (Monolith), lupine (Obornik), white pea, striped sunflower, sorghum. A detailed description of the method and the course of the experiment is illustrated by the example of lupine seeds (Obornicki), that is why, on the basis of the literature, more important features and properties have been characterized.

Source: photo. Ł. Gierz / Źródło: fot. Ł. Gierz

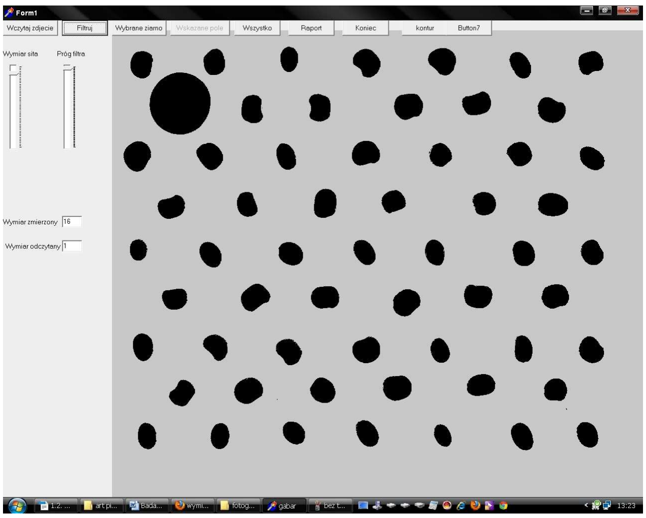
Fig. 1. Lupin Obornicki
Rys. 1. Łubin Obornicki

Lupine seeds (Obornicki) are brown-gray seeds, with marbled texture of the surface (on the dark background there are brighter spots), kidney shape. The weight of 1000 seeds is about 180 g. The recommended sowing standard is 140-160 kg/ ha, while the row spacing is 15-25 cm, depth is 3-4 cm. Optimal sowing date 10-15 April [12]. Figure 1 shows photographs taken at the upper Lupin Obornicki grain.

5. Description of the method

On prepared glass plates with dimensions 100x100 mm randomly selected seed samples of the given plant species obtained from the Poznań Seed Center were sticked. These plates were then photographed using a 5- megapixel digital camera. A disc 16 mm in diameter was placed on the photographed seed plates as a standard length.

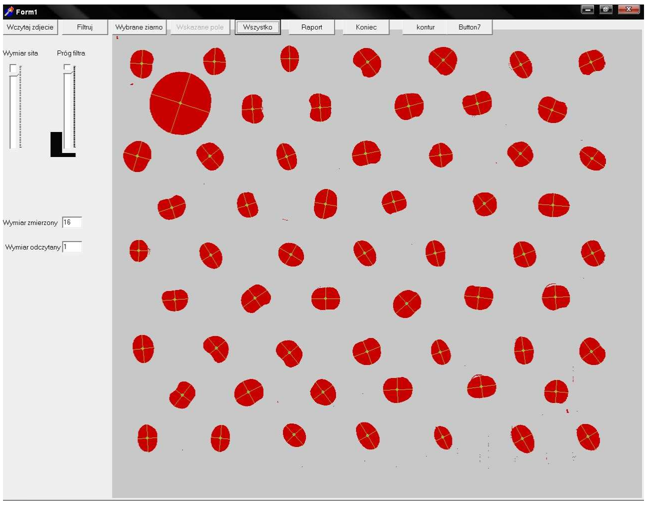
Photographs were pre-processed using the paint.net web-based program and then the correct measurements were made using a program written in the Gabar Machine Department [9]. This program automatically performs the binary image based on the accepted threshold of brightness of the objects (see Figure 2 for an example of binarization on the example of lupine "Obornicki") and then outlines the contours of all the seeds in the seed frame (see Figure 3 for an example of isolated contours on the example of lupine "Obornicki" grains), calculating their geometric characteristics such as surface area, overall dimensions (length, width), moments of inertia and center of gravity. The master object is measured first - in our case a disc 16 mm in diameter - which allows the seed images to be automatically scaled according to the known dimension of the disc.



Source: screen dialog box of program "Gabar"
Źródło: screen okna dialogowego programu „Gabar"

Fig. 2. Image binarization in "Gabar"
Rys. 2. Binaryzacja obrazu w programie „Gabar"

The results of the measurements and calculations for each sample are placed in a disk file. The results of the measurements are then subjected to statistical processing by calculating the average and mean square deviation of the seed dimensions. Once the measurement is complete, you can print a measurement report - the sample report shown in Figure 4.



Source: screen dialog box of program "Gabar"/ Źródło: screen okna dialogowego programu „Gabar”

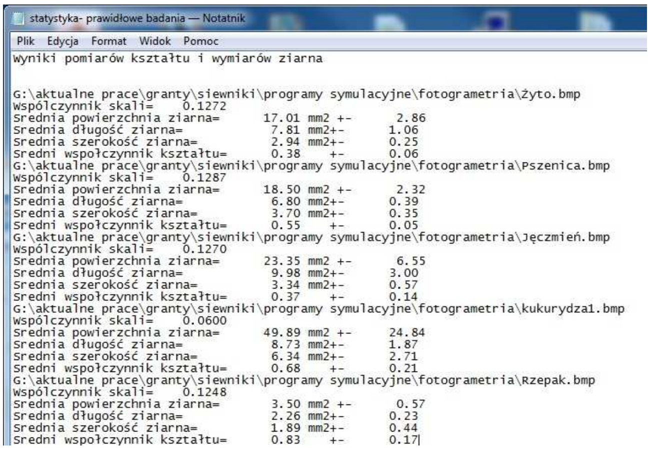
Fig. 3. The extracted contours of the seeds in the "Gabar"
Rys. 3. Wyodrębnione kontury nasion w programie „Gabar”

6. Research results

Based on the measurements, basic seeds of 16 crop plants were characterized for the sowing, transport, cleaning, screening, selection and shredding of seeds. The results of photogrammetric measurements for 16 plant kernels are summarized in Table 1.

In order to perform an accuracy analysis of the granulometric method of measuring grain dimensions, it was decided to use measurements of the same grains with a caliper of 0.01 mm accuracy.

The results of the analysis of accu-racy are presented in Table 2. Based on the measurements' accuracy analysis of grain size, the maximum square deviation (absolute error) is 0.01 mm. Thus, the measurements of grain size on the test bench for dimensional and shape measurements are satisfactory and can be used as boundary conditions when designing work machines. Currently the photogrammetric method is used for the geometric characterization of kernels for the validation of mathematical models of grain movement in pneumatic seed drills, although it is not excluded from its use for the examination of the shape of other materials such as wood chips.



Source: printout of a text file of collected measurements in "Gabar" / Źródło: wydruk pliku tekstowego zebranych pomiarów w programie „Gabar”

Fig. 4. The report on the results of measurements in the "Gabar"
Rys. 4. Raport z wyników pomiarów w programie „Gabar”

Table 1. The results of photogrammetric measurements for selected types of grains
Tab. 1. Wyniki pomiarów fotogrametrycznych dla wybranych rodzajów ziaren

No	Species, variety	TSW [g]	Length [mm]	Width [mm]	Shape Factor	Surface area [mm^2]
1.	Rye, Dańkowskie złote	32,5±7,5	7,81±1,06	2,94±0,25	0,38±0,06	17,01±2,86
2.	Winter wheat, Tulsa	42,5±7,5	6,80±0,39	3,70±0,35	0,55±0,05	18,50±2,32
3.	Barley winter, Titus	45,5±2,5	9,98±3,0	3,34±0,57	0,37±0,14	23,35±6,55
4.	Winter triticale, Borwo	42±7	7,50±0,46	3,0±0,30	0,40±0,04	16,36±2,02
5.	Oats, Bingo	28,5±2,5	10,96±1,89	3,08±0,52	0,30±0,1	25,40±4,88
6.	Corn (Celux)	250±2	8,73±1,87	6,34±2,71	0,68±0,21	49,89±24,84
7.	Winter rape, Monolith	5,2±0,1	2,26±0,23	1,89±0,44	0,83±0,17	3,50±0,57
8.	Winter oil-yielding rape, Brachina	3,5±0,1	1,71±0,61	1,04±0,57	0,64±0,26	2,40±0,49
9.	Lupine (Obornicki)	179,5±3,5	7,24±0,48	5,67±0,56	0,77±0,08	32,62±4,88
10.	Lucerne, Planet	2,6±0,9	2,2±0,26	1,32±0,27	0,58±0,11	2,51±0,44
11.	White pea	275±25	8,03±0,37	7,31±0,42	0,91±0,04	45,23±4,03
12.	Peluszka, Milwa	175±25	8,01±0,39	6,93±0,41	0,87±0,05	41,23±4,12
13.	Southern hempen	22±4	4,84±0,49	3,65±0,53	0,75±0,07	12,97±3,13
14.	Sunflower striped	84±2	11,05±0,61	4,48±0,50	0,41±0,06	39,77±5,23
15.	Sorghum	37,5±1,5	4,79±0,47	2,85±0,29	0,59±0,06	9,23±1,30
16.	Mustard	7±0,5	2,30±0,36	1,93±0,46	0,83±0,15	3,67±0,68

Abbreviations: TSW- mass of 1000 seeds

Source: own elaboration / Źródło: opracowanie własne

Table 2. The results of the accuracy measurement of grain size
Tab. 2. Wyniki badań dokładności pomiaru wymiarów ziaren

No	Species, variety	Average length [mm]			Average width [mm]		
		MF	MS	B	MF	MS	B
1.	Rye, Dańkowskie złote	7,81	7,81	0	2,94	2,94	0
2.	Winter wheat, Tulsa	6,80	6,81	0,01	3,70	3,70	0
3.	Barley winter, Titus	9,98	9,97	-0,01	3,34	3,33	-0,01
4.	Winter triticale, Borwo	7,50	7,50	0	3,0	3,0	0
5.	Oats, Bingo	10,96	10,96	0	3,08	3,07	-0,01
6.	Corn (Celux)	8,73	8,73	0	6,34	6,34	0
7.	Winter rape, Monolith	2,26	2,25	-0,01	1,89	1,89	0
8.	Winter oil-yielding rape, Brachina	1,71	1,71	0	1,04	1,04	0
9.	Lupine (Obornicki)	7,24	7,23	-0,01	5,67	5,66	-0,01
10.	Lucerne, Planet	2,20	2,20	0	1,32	1,32	0
11.	White pea	8,03	8,03	0	7,31	7,31	0
12.	Peluszka, Milwa	8,01	8,01	0	6,93	6,92	-0,01
13.	Southern hempen	4,84	4,84	0	3,65	3,64	-0,01
14.	Sunflower striped	11,05	11,05	0	4,48	4,48	0
15.	Sorghum	4,79	4,79	0	2,85	2,85	0
16.	Mustard	2,30	2,30	0	1,93	1,93	0

Markings: MF - photogrammetric measurements, MS - measuring caliper, B - Measurement error

Source:own elaboration / Źródło: opracowanie własne

7. Conclusions

Based on the measurements made, the following conclusions can be drawn:
1. The photogrammetric method of measuring the geometrical features of the kernels allows for a significant improvement and quickening of the process of obtaining data;
2. The procedures implemented in the "Gabar" computer program allow for proper measurement and calculation. Verification of the accuracy of this method has shown that the maximum square deflection of measured measurements is 0.01 mm;
3. The photogrammetric method for the price of shapes and dimensions can be used to evaluate the size of recycled raw materials such as wood chips, green PVC foils that are increasingly used as alternative fuels or recycled materials.

8. References

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