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MEASUREMENT OF GRAIN SURFACE ROUGHNESS*

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A b s t r a c t. In the research on the friction of vegetative grain-structure, an essential problem lies in the appropriate determination of the condition of the surface layer of elements in mutual contact. The analysis must define both tensile strength parameters and the surface topography. Most frequently, surface geometry is defined by roughness. Compared to the traditional methods applied for the construction materials, the measurement of roughness in this case is more difficult due to the cellular structure and multifarious shapes of individual skeletons, while low surface hardness (especially at significant humidity) excludes the possibility of applying mechanical methods. For these reasons, an attempt was made to develop a rapid and simple method for the measurement of grain surface roughness - relying on the optical procedure.

The measurement bench consists of a stereo-microscope with a trinoculare and a camera linked to the computer through an analogue-digital processor. The entire measurement set is equipped with a MultiScan software, where a special picture processing was applied - as described below in the paper. A computer analysis of the picture allows to carry out an automatic and precise measurement of the profile roughness in any selected point on the grain surface.

K e y w o r d s: surface roughness, relief surface, grain

INTRODUCTION

Most research works on grain bulk subjected to static and dynamic strains, puts an increasing emphasis to the condition of the outer layers of interfacing elements. Both resistance parameters and surface topography are considered [1].

In the studies focusing on the interface mechanics, the following factors are identified in relation to the surface topography: undulation, orientation and roughness of the surface. The former two values are inherently related to the construction materials and the mode of their processing (usually mechanical machining). On the other hand, surface roughness can be defined also for an individual plant grain in granular bulk. It is defined as the total roughness of the real surface with a relatively fine texture, i.e., small intervals between the neighbouring surface ridges [2]. Such ridges can be measured as the deviation of the observed profile from the adopted reference line, at the arbitrarily defined length.

The roughness profile may be defined in the following ways:

- by the height parameters (e.g., elevation height of the roughness ridge, depth of the profile concavity, the maximum height of the roughness ridge, etc.);
- by horizontal parameters (average inter-ridge distance, and average distance between local profile extrusions);
- by the parameters defining the shape of surface disturbance (e.g., radius of the summits curve, or the relative length of the profile).

However, in the majority of studies, the main roughness parameter is defined as the arithmetic mean deviation of the profile R_a, determined as the mean value of the distance between the observed profile points and the mean line, at the length of the measured interval.

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Many possible methods to measure surface roughness are quoted in literature. However, none of them is sufficiently universal to cover the whole height range of the measured elevations, which may vary from 10^{-10} m (in the most smooth elements of optical equipment) and hundreds of micrometers 10^{-3} m (surfaces of large elements of power generating machines).

Depending on the nature of the measurement, two groups of methods can be identified:

linear - where transformation of the surface shape occurs along the adopted measurement interval;

surface-based - where the measurement is of the total roughness of a given surface is taken.

Definition of the roughness of vegetative materials is more complex due to curvilinear and multifarious shape of the studied surfaces - which excludes application of many popular methods, such as, e.g., volume-based measurement, pneumatic or reflexive method [3]. What is more, simple and rapid profilometric methods based on the mechanical contact, which use a steel needle as a sensor cannot be applied here as the needle may easily damage soft structure of the studied material. Considering the above factors, it seems that the optimum method to measure surface roughness of the vegetative materials is in optical examination. Of course, it is an indirect method where the concept of roughness is based on the measurement of the height of image disturbance of the profile in the microscope image sights (effect of illumination of the studied surface with a flat light beam); alternatively, a comparative analysis is made of the relief of the studied surface in relation to the model surface (applying optical elements).

THE OBJECTIVE AND SCOPE OF RESEARCH

Usually, measurements of roughness of vegetative material surfaces rely on traditional instruments, which are conventionally applied to construction materials. This type of equipment is relatively expensive, has limited application, and measurements are very complex (work-intensive). Therefore, the objective of the present study was defined in the following way: to develop a simple and rapid method to measure surface roughness of biological materials.

Cost/benefit analysis of various methods of measurement carried out in the view of the adopted objective, led to the following project assumptions:

measurement of surface roughness shall be made optically;

the applied equipment must provide the possibility means for rapid data registration on a computer disque;

the concept of the measurement shall the comparative analysis of the studied surface relief in relation to the model surface;

the measuring procedure should be relatively simple; no special training for personnel is required.

As mentioned above, the measurements aiming at the definition of shape, geometrical dimensions and roughness of grain bulk surface are difficult and labour intensive. These difficulties are avoided in computer analysis of the picture taken by a camera, scanner or microscope [4]. Computerised analysis has the following advantages: repeatability and reproductibility of results, highly objective measurements, shortened time-consuming research, broader research application. Therefore, it was decided that the underlying concept of developing measuring method shall consist in the computer registration of pictures of the studied surface and an automatic comparative analysis with a model surface of a pre-defined height of R_a microridges.

A MEASURING METHOD FOR SURFACE ROUGHNESS

In order to implement the project objectives, an suitable measuring bench was constructed. The diagram of the bench can be seen in Fig. 1. The studied biological material is placed on the support of the stereomicroscope HUND SM-33 working in the light reflected with 14 - 90x blow-up. Next, a beam of light is thrown at the work surface from the laboratory

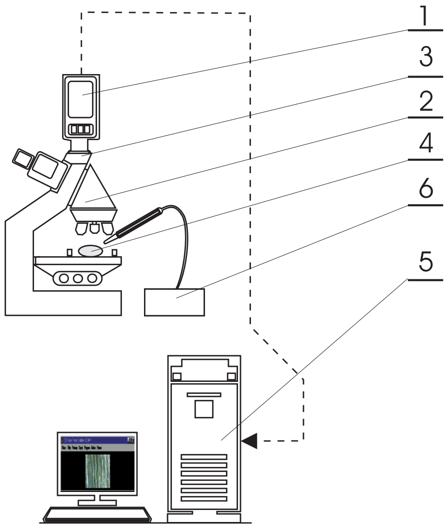

Fig. 1. Diagram of a measuring bench: 1 - high definition camera, 2 - stereoscopic microscope, 3 - mount jack between the camera and microscope, 4 - studied material, 5 - computer with a Show-Time Plus card, MultiScan programme, individual macrodefinitions and applications, 6 - laboratory mini reflector.

minireflector. Having regulated the picture sharpness, the picture obtained can be directed to the PC-type computer. This is done through a Panasonic closed-circuit camera mounted on the microscope trinocular (with a proper C-mount jack). The camera provides a sufficiently high picture definition (625 lines, 4.8 10^5 pixels). The picture is then processed by an analog-to -digital converter of a frame graber type - Show Time Plus.

The analysis of the picture of the surface obtained as a bit - map, is processed by the Multi Scan programme v.6.08, and its supporting applications. The concept of the analysis is shown in Fig. 2.

A coloured picture from the camera is transformed into a bit-map with various shades of grey. Next, the user selects the section of surface to be analysed in more detail. After introduction of the macrodefinitions for “profile detection”, this new bit-map is being filtered in order to eliminate “noises”. Later, a mouse should be used to define measuring intervals and to register the obtained profiles of microridges (in various shades of grey).

After data conversion, it is possible to analyse the registered microridge profile by another system application. The operation of this application consists basically in comparing the studied profile with the model microridges which had been entered earlier in the so-called microridge scale table (as a result of tests carried out on model plates). The final effect consists in the calculation of R_a μm. This value is provided as the result of a single measurement, or the mean of five measurements (PN-73/M -04251).

RESULTS

The bench described above was used to taken a number of measurements aiming at the definition of the influence of moisture content in the material on the roughness scale of the surface. *Grain* type wheat grain was applied as the research object. In order to homogenise dimensions, grains were selected with laboratory sieves. The most numerous fraction was chosen for further analysis.

The first measurements were taken on the atmospherically dry grain with 12% moisture content. Next, the material was wetted further by an addition of water and closing in an air-tight container which was periodically turned. In this way, wheat with 26% moisture content was obtained. A series of measurements was taken of this material. Next, the grain bulk was dried to obtain successively 21, 16 and 8% moisture content in dry bulk.

The measurements of surface roughness were taken at the side and back wall of each grain kernel. Additional measurements were made in two perpendicular directions: along and across the longest axis of the karnel. Five repetitions were made for each level of moisture content.

The results obtained were statistically analysed. ANOVA tests in triple classification with recurrence were used. The exogenous variables were: moisture content in the analysed material, place of measurement and direction of

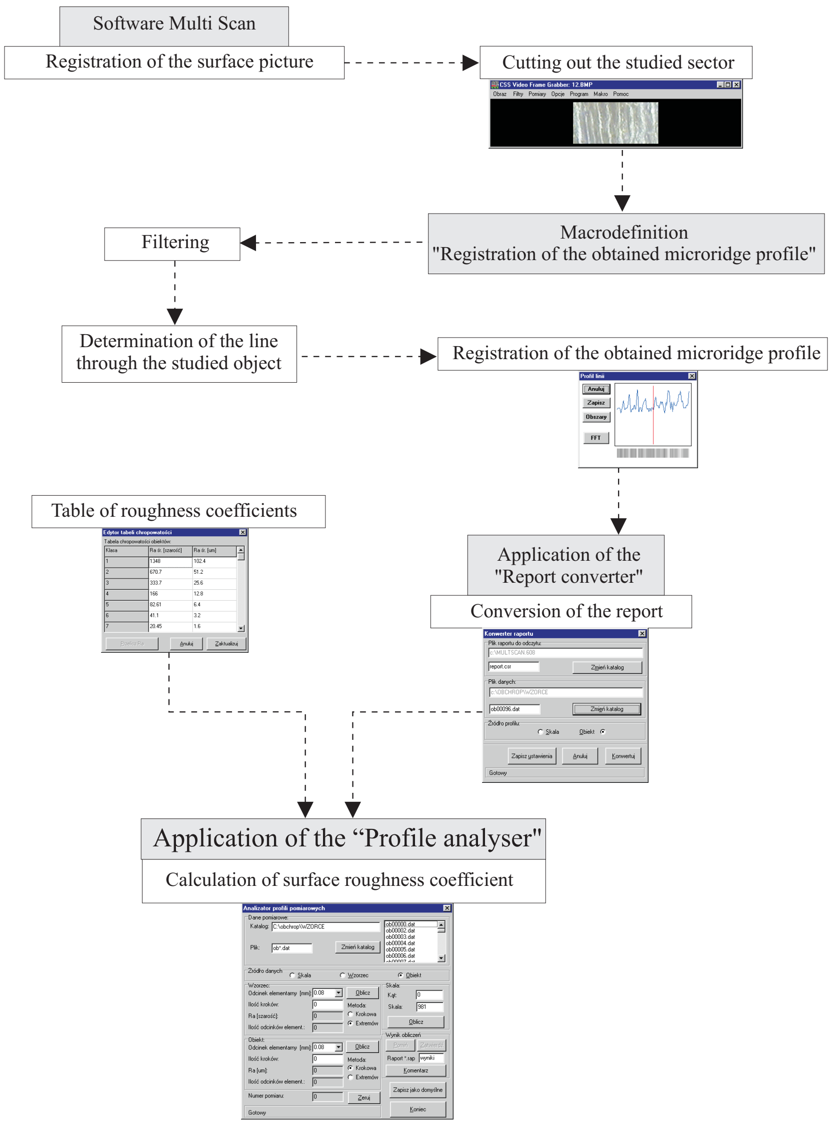

Fig. 2. A functional diagram of the method used for defining surface roughness of plant materials.

measurement. Statistically significant relation was found for the influence of all the above mentioned variables on the value of the arithmetic mean deviation of the R_a profile. On the basis of the Duncan’s test, the interval of moisture content was defined in the range of 12-16%, where the roughness coefficient is the lowest. For the values below this interval, surface roughness was greater. This is probably caused by an excessive grain dryness and the development of the so-called thermal shrinkage. Moisture content in vegetative materials is influenced both by the surface-layer of water in the capillaries and within the cells. The entire system remains in continuous movement oriented at the sustained balance with the environment and internal processes. Water evaporation from the surface layer results in disequilibrium and leads to cell deformations of the surface layer. With the moisture content above 16%, water initially fills micropores and then, cells - which results in increased intercellular distances, and thus also surface roughness. This hypothesis needs to be confirmed by further research.

Duncan's test showed also the existence of differences between the roughness of the back-of-the-grain surface and roughness of grain side walls. The influence of the measuring directions was also significant. Thus, roughness of the studied material surface is anisotropic and is considerably greater when the measurement is taken across the longest axis of the kernel. This fact is justified by the anatomic and morphological structure of wheat grain. Therefore, it is necessary to indicate ridge height values and measuring conditions when quoting results in scientific publications.

The results obtained (Fig. 3) were approximated (individually for all the measuring conditions) by third degree curves, where the highest convergence was found between the theoretical curve and experimental points (Table 1). It should be emphasised that in the case of measurements taken at side walls, along the longest axis of the kernel, this convergence is very high.

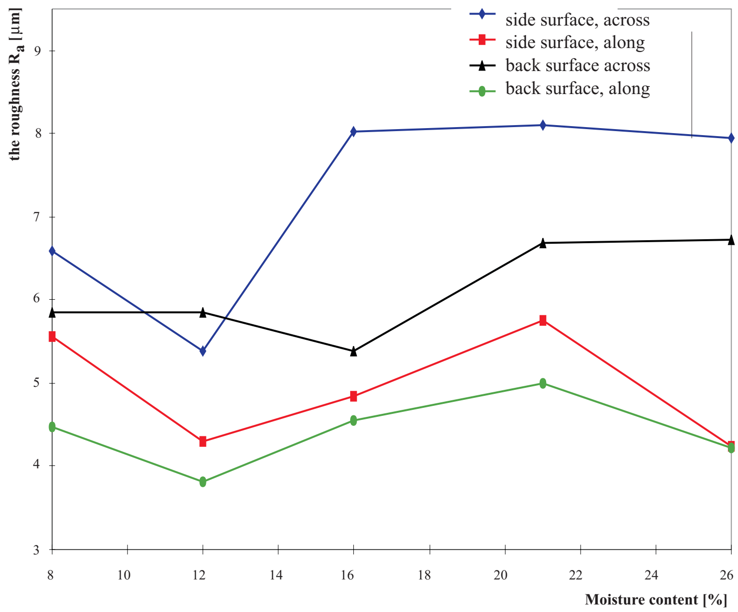

Fig. 3. Change in surface roughness in relation to the moisture content.

T a b l e 1. Results of curvilinear approximation

Place and direction of measurement	Model of approximation $y = ax^3 + bx^2 + cx + d$				
	a	b	c	d	R
Side surface, across	-0.00328	0.1624	-2.3359	16.38	0.855
Side surface, along	-0.00389	0.196	-3.0545	19.44	0.956
Back surface, across	-0.0012	0.0574	-0.9385	10.29	0.868
Back surface, along	-0.00229	0.1138	-1.7065	11.99	0.972

Equally high degree of fit (R = 0.972) was found for the back area of the kernel and the measurements taken across the axis. These findings give a significant guideline for the development of standards (norms) for measuring grain surface roughness.

CONCLUSIONS

The paper presents an original optical method used for the measurement of roughness of the wall of vegetative material, consisting in an automatic computerised comparison of the scanned surface of the studied material in relation to model pictures of surfaces with the pre-established R_a value. The measuring bench designed and constructed for the experiment is supported by a professional programme for computer picture analysis (Multiscan), with appropriate macrodefinitions and support applications. Thus, it was possible to perform rapid, simple and objective determination of the value of mean arithmetic deviation of the ridge profile R_a, treated as the main parameter defining surface roughness.

Preliminary measurements made with wheat kernels enabled to draw conclusions, providing guidelines to further research:

1. The calculations showed that moisture content in grain is a factor determining the height of R_a microridges. Wheat kernels were the smoothest at the water content of 11-16%.

2. Relation between surface roughness and moisture content can be fully described by the third degree polynomial.

3. Statistically significant differences were found between surfaces various location on the kernel.

4. It is necessary to continue this type of research when using other plant materials. The research objective should be identified as the definition of the standard (norm) for the determination of plant material surface roughness.

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