Electronic Journal of Polish Agricultural Universities is the very first Polish scientific journal published exclusively on the Internet, founded on January 1, 1998 by the following agricultural universities and higher schools of agriculture: University of Technology and Agriculture of Bydgoszcz, Agricultural University of Cracow, Agricultural University of Lublin, Agricultural University of Poznan, Higher School of Agriculture and Teacher Training Siedlce, Agricultural University of Szczecin, and Agricultural University of Wroclaw.

ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2007
Volume 10
Issue 1
Topic
AGRICULTURAL ENGINEERING

V. V. LISOWSKY, W. TANAŚ. 2007. NEW SENSOR FOR THE MICROWAVE CONTROL OF MOISURE IN FLOUR-MILLING PRODUCTION **Electronic Journal of Polish Agricultural Universities**,
Agricultural Engineering, Volume 10, Issue 1.
Available Online http://www.ejpau.media.pl/volume9/issue1/art-12.html

NEW SENSOR FOR THE MICROWAVE CONTROL OF MOISURE IN FLOUR-MILLING PRODUCTION

Vladislav V. Lisowsky[1], Wojciech Tanaś[2]
[1]*Belarussian Agricultural Technical University, Minsk, Belorus*
[2]*Faculty of Production Engineering, Agricultural University of Lublin, Poland*

ABSTRACT

This paper describes the microwave sensors for grain and grain products' moisture control in technological processes of their production. There were used two sensors at the output and at the input of the damping machine. Different algorithms of operation, has allowed optimizing the flour-milling equipment regarding to the highest quality (lowered ready-made product losses) at the output of flour.
It was shown, that the effect of electromagnetic dispersion on superficially moistened grain layer must be taken into account at rapid moistening.

Key words: sensor, moisture measurement, microwave, grain, flour-milling

INTRODUCTION

Under the conditions of grain density stabilization and of automatic temperature correction, it is possible to apply one-parameter sensor, registering electromagnetic energy attenuation in the moist material. However, measuring uncertainty can make up to 30% and more, when non registering the dispersion loss of energy.

METHODS AND RESULTS

The process of grain dehydration allows a rather easy stabilizing of the stuff flow controlled. Here, it is enough to control only one dimension, e.g. the electromagnetic wave attenuation coefficient α (when the temperature is corrected automatically) – fig. 1. Thus, the relation between the attenuation N in the sample with the thickness d, density ρ and the moisture W will be as follows [1]:

$$N = 8.686 \cdot \alpha_{\text{H}} \cdot W \cdot \rho \cdot d \qquad (1)$$

The factor of attenuation $\alpha_{н}$ within the framework of linear model will be determined by expression:

$$\alpha_H = \alpha_{HB} \cdot q_{HB} + \alpha_{HP} \cdot q_{HP} + \alpha_{H0} \cdot q_{H0}, \qquad (2)$$

where: $\alpha_{HB}, \alpha_{HP}, \alpha_{H0}$ – factors of attenuation of an electromagnetic wave in water bound, polysorption and free respectively;

q_{HB}, q_{HP}, q_{H0} – volumetric concentration of water bound, polysorption and free respectively;

From where we get:

$$\alpha_H = \Phi \frac{\rho_d}{\rho_H}\left[\frac{W}{(1-W)}\alpha_{но} + \frac{\mu S_S}{N_A \sigma} a_m f_1(w, s_S, a_m)(\alpha_{нп} - \alpha_{но}) + \frac{W_{cr}}{1-W_{cr}}(\alpha_{HB} - \alpha_{но})\right] \qquad (3)$$

where:
Φ – factor of filling;
ρ_d, ρ_H – density of a dry material and water;
μ – gramme molecular weight of water;
S_S – a specific surface of a grain (wheat);
$N_A = 6.022 \cdot 10^{23}$;
$\sigma = 3 \cdot 10^{-8}$ – landing place of one molecule of water on a surface of a firm phase;
$a_m = 100$ – a maximum quantity of monolayers of water occupied with a moisture polysorption in the given material;
$W_{cr} = 10\%$ – the critical moisture appropriate to transition from bound water in a grain to water polysorption.
$f_1(w, s_s, a_m)$ – the function describing ratio between free and bound water.

Function $f_1(w, s_s, a_m)$ according to model of Ivens-Busker [3] in which it is supposed, that speed of change of the given form of moisture in the process of moistening is directly proportional to a part sorption volume free from this moisture. Hence it is possible to write down:

$$\frac{dq_{HP}}{dQ} = 1 - \frac{q_{HP}}{q_{HPm}} \qquad (4)$$

where: q_{HP} – volumetric concentration of a moisture polysorbtion;

$Q = \frac{P_H}{\rho_H \cdot V}$ – relative volumetric moisture of a material, i.e. relative quantity of water (P_H) in unit of volume $(V = q_{HC} + q_{HP} + q_{H0})$;

Integrating (3), with the account that at $Q = Q_{HP}, q_{HP} = 0$, we receive

$$q_{HP} = q_{HPm} \cdot \left(1 - e^{\frac{Q_{cr} - Q}{q_{HPm}}}\right) \qquad (5)$$

In this kind expression (4) is inconvenient to use since all volumetric concentration of water included in it depends on the factor of filling Φ. Knowing the specific surface of the material S_S and the maximum quantity of monolayers of water polysorption a_m, q_{HPm} it is possible to find as follows:

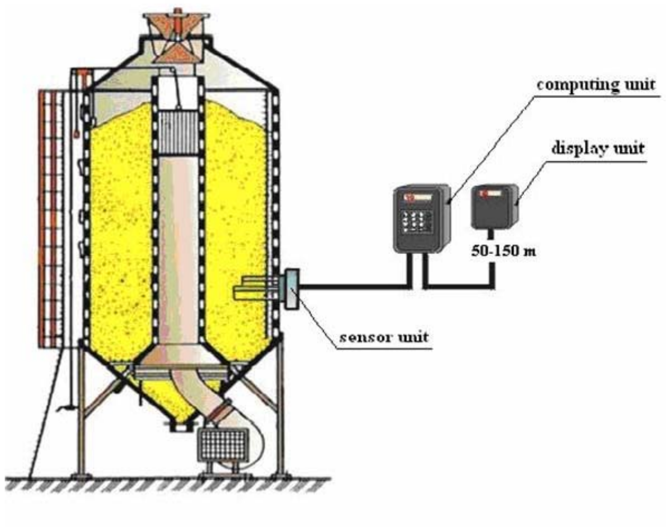
$$q_{HPm} = \frac{\mu \cdot \rho_d \cdot S_S}{N_A \cdot \rho_H \cdot \sigma} \cdot a_m \cdot \Phi \text{, then}$$

$$q_{HPm} = \Phi \cdot \frac{\rho_0 \cdot \mu \cdot S_S}{\rho_H \cdot N_A \cdot \sigma} \cdot a_m \left[1 - \exp \frac{(W_{cr} - W) \cdot \sigma \cdot N_A}{(1 - W_{cr}) \cdot (1 - W) \cdot \mu \cdot S_S \cdot a_m} \right] \tag{6}$$

Hence function $f_1(w, s_S, a_m)$ will be determined by expression

$$f_1(w, s_S, a_m) = 1 - \exp \frac{(W_{cr} - W) \cdot \sigma \cdot N_A}{(1 - W_{cr}) \cdot (1 - W) \cdot \mu \cdot S_S \cdot a_m} \tag{7}$$

Fig. 1. Scheme of main units installation on grain dryer



The calculation of dielectric characteristics of wheat model can be made, having accepted the following values [1, 2, 4, 6]:

ρ_0 = 1.2 g·cm^{-3}; S_s = 220 m^2·g^{-1}; a_m = 100; W_{cr} = 0.1;

$\varepsilon_{H0\infty} = \varepsilon_{HP\infty} = \varepsilon_{HC\infty} = 5.1$; $\varepsilon_{HBS} = 60$; $\varepsilon_{HPS} = \varepsilon_{H0S} = 80{,}4$; t = 20°C;

$\lambda_{H0m} = 1.79$ cm; $\lambda_{Hcm} = 377$ cm; $\lambda_{HPm} = 9.5$ cm;

ΔH_{HB} = 15 kcal·mol^{-1}; ΔH_{HP} = 1 kcal·mol^{-1}; ΔH_{H0} = 4.6 kcal·mol^{-1}

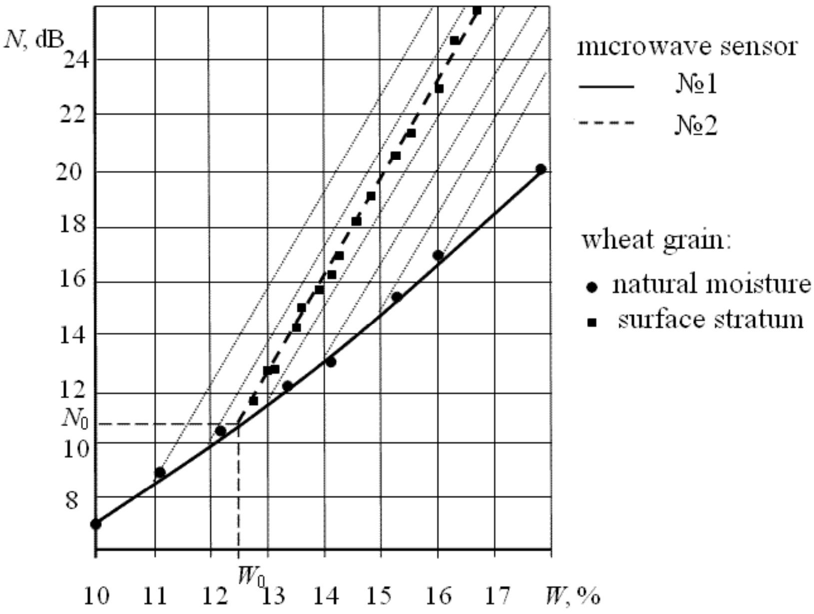
The results of calculation, in view of that the factor of filling Φ is function of moisture (table 1) content lead to the dependence different from graduation for Microradar 113 no more than on 10% (fig. 2.).

Table 1. Dependence of filling coefficient *Φ* on wheat moisture

W, %	8	12	16	20	24	28	32	34
Φ	0.60	0.54	0.50	0.44	0.43	0.41	0.39	0.37

However, since the flour-milling industry sticks to additional damping of grain from 12-14% to 15.5-16%, it is essential that the influence of the free and bound water should be taken into consideration, which means switching to another calculation algorithm. To serve that purpose, a new modification of moisture indicator has been developed. It is equipped with two microwave sensors (placed at the entrance and output of the damping machine) and a computing unit, which functions along two patterns.

Fig. 2. Calculated dependence *N(W)* for microwave sensor № 1 and № 2 in function *W*



The second sensor control installed at the output of the moistening machine uses the following algorithm:

$$N = N_0 + \alpha_H \cdot k \cdot (W - W_0); \quad (8)$$

When $\alpha_H = \alpha(W)$ – factors of attenuation and is defined by calculated way under known dielectric properties for free water [6]. Thus the calculation results give moisture value more than 30% overestimated.

At the equation deduction the assumption (1) has been made, that in homogeneities dispersion can be neglected which is true for the uniformly moistened grain. However the technology of flour-milling production demands transient moistening of grain surface stratum. Thus the measuring result of electromagnetic energy dispersion effect in this stratum brings in considerable contribution, while the moisture content of caryopsis's other layers does not change.

The effects of dispersion and attenuation are studied well in radio-meteorology. The calculation of dispersion coefficient k_d is made by formula [6]:

$$k_d = \frac{12\pi^4 a^4}{\lambda^4} \cdot \frac{(m^2 - 1)}{(m^2 + 2)} \quad (9)$$

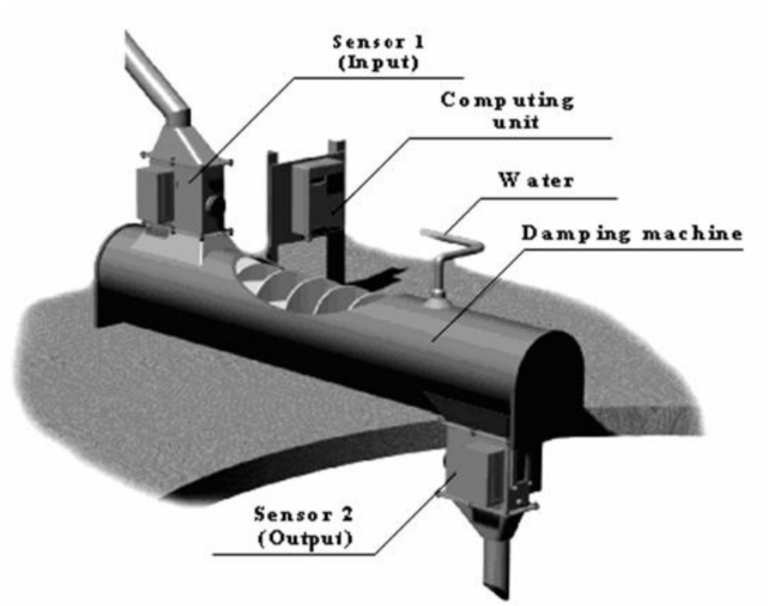
here: a – is a sphere's medial radius with the equivalent surface equal the caryopsis surface;
$m = n - j\chi = \sqrt{\varepsilon' - j\varepsilon''}$ – is a refraction factor.

Under known dielectric properties of the free water [6] taking into account that $\varepsilon' = n^2 - \chi^2$, $\varepsilon'' = 2n\chi$ it is easy to calculated parameter k_d, which for $\lambda = 3.2$ cm is 4.367.
With the embedding of settlement adjusting coefficient $k' = 1.287$ we finally gain the expression which links moistened grain signal attention N with the weight moisture W:

$$N = N_0 + 3.56(W - W_0) \quad (10)$$

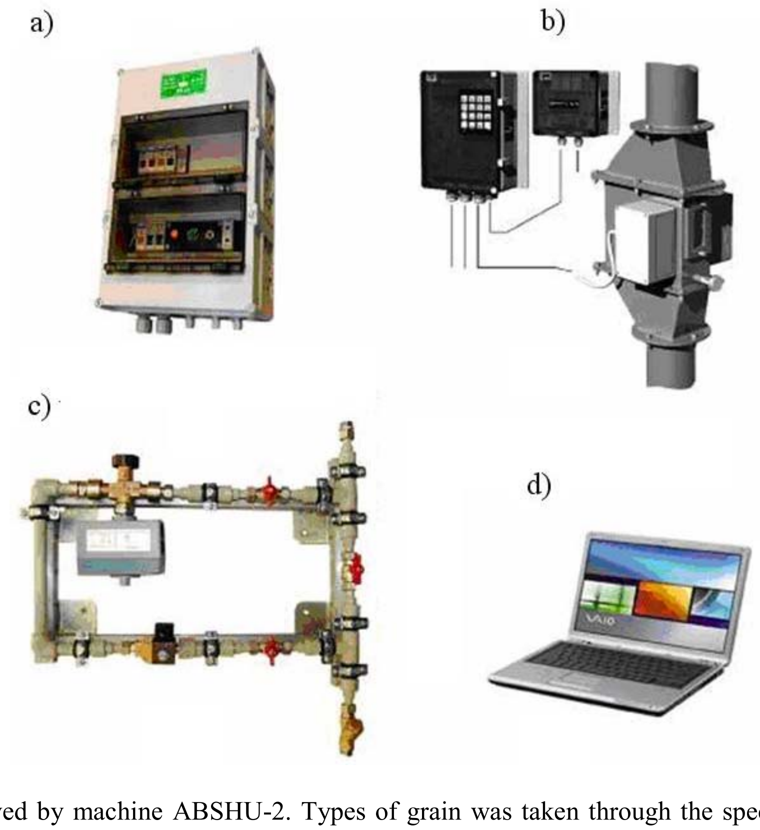
The calculation and experimental research results of wheat grain for temperature $t = 20°C$ and wavelength $\lambda = 3.2$ cm are given in figure 2.

Fig. 3. Scheme of main units installation on damping machine



The researches of experimental results, well in accord with the theory, and the record of industrial application of the automatic additional damping systems based on Microradar 113-2 (fig. 3, fig. 4) show the possibility of high-precision maintenance of the finite moisture of grain (less than ±0.2%) [5].

Fig. 4. The damping machine is driven by the basic elements of the automatic control system: a) commutation and transforming unit; b) the moisture meter Microradar 113-2 with one of sensors; c) the unit of controlling the quantity of water; d) the main computer



This result was received by machine ABSHU-2. Types of grain was taken through the special windows, where is sensor 1 and sensor 2. the analysis of the grains on the moisture fulfilled by the vacuum temperature method on the licensee set OVZ-1 in a laboratory. For the every point sensor's watching by the moisture measurement Microradar 113-2 fit the mean of the results for two types of grains. The decline between two experiments did not exceeded 0.05% of moisture, if it did the experiments repeated.

CONCLUSION

The application of one computing unit with two sensors at the output and at the input of the damping machine, using different algorithms of operation, has allowed optimizing the flour-milling equipment functioning. That provided the highest quality at the maximum output of flour and has essentially lowered ready-made product losses.

REFERENCES

1. Benzar V.K., 1974. Thechnique of Microwave Aquametry. Vycheichaja chkola, Minsk, p. 352 [in Russian].
2. Benzar V.K., Tzentziper B.L., Renhart I.I., 1984. Displacement of Dielectric Relaxation Peak of Water in Grain. Izvestiya AN BSSR 4, 72-76 [in Russian].
3. Busker L.H., 1968. Microwave Moisture Measurement. Instrument and Control Systems 12.
4. Kraszewski A.W., Trabelsi S., Nelson S.O., 1998. Comparison of density-independent expressions for moisture content determination in wheat at microwave frequencies. J. Agric. Eng. Res., 227-237.
5. Renhart I., 2001. The Control of Moisture of Rocks by Methods of Microwave Aquametry. 4th International Conference on “Electromagnetic Wave Interaction with Water and Moist Substances”, Weimar, pp. 372-379.
6. Rosenberg V.N., 1972. Dispersion and attenuation of electromagnetic energy by atmosphere particles. Gydrometeoizdat, Leningrad, p. 398 [in Russian].

Vladislav V. Lisovski
Belarussian Agricultural Technical University of Minsk
Naturalistov str. 4-9, Minsk 220023, Belorus
tel./fax +375 17 2367 504
home +375 17 267 88 75
GSM +375 297 77 88 75
e-mail: meridian2738e@mail.ru

Wojciech Tanaś
Agricultural University of Lublin
28 Głęboka Street, Lublin, Poland
tel./fax (+48 81) 532 94 63
e-mail: wojciech.tanas@ar.lublin.pl
