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INFLUENCE OF WATER MASS TRANSFER ON ACCURACY OF GRAIN HUMIDITY MEASUREMENT INTRODUCTION

The paper contains the results of experimental research of electro physical parameters of grain, on the basis of which the reasons leading to reduction of measurement accuracy of humidity performed by dielectric moisture meters are revealed. The authors suggest ways to improve the accuracy of measurements of complex permittivity of grain crops.

Keywords: *dielectrical drymeter, grain humidity, permittivity of grain-crops.*

Ukraine is one of the largest world producers of grain, manufacturer of competitive grain driers, but the country does not have modern systems of control and monitoring of grain drying processes – devices of Ukrainian production that could meet the requirements regarding the price, accuracy, reliability and provide the possibility to control grain humidity in real time are not available on the market. Moisture meters, manufactured in the USSR are not used because of their low accuracy. The usage of foreign moisture meters for greater part of agricultural enterprises is not possible because of their high price. The process of grain drying is one of the most energy consuming and important in grain storage and processing cycle. This is clue to direct losses, caused by the quality decrease and the lack of possibility of storage in conditions where the humidity requirements cannot be met as well as to the increase of energy expenditures of drying process. Volume of losses, taking into account the above-mentioned factors, even on the level of separate enterprises reach tens thousand of hryvnas per season [1]. Thus, this problem is of paramount importance for agrarian branch of the national economy.

Analysis of research, carried out and publications

Direct and non-direct methods are distinguished in the process of grain humidity measurements. Direct methods are based on the extraction from test sample by any means of the moisture and weighting of sample mass before and after moisture extraction.

Thermo gravimetric devices are most widely used in this group of methods. Such moisture meters provide high accuracy of the results (error is $\pm$ 0.1%) but measurements take much time (from 20 min. to several days) [2]. Since mid-90s of the last century lab. moisture meters of foreign production are available of Ukrainian market. These devices have built-in balance and infra-red source of radiation (sometimes such devices are equipped with miniature mill intended for grinding test sample of grain). Due to combination of drying oven, balance and microprocessor in one unit it is possible to reduce time of measurement and improve the convergence of results and provide the limit of analyzer possible error at the level of $\pm$ 0.2…0.3% [3]. But for the usage of such installations in laboratories they are to be adapted to operation modes accepted in our country. Thus calibration tests are to be carried out that leads to additional expenditures, besides it should be noted that practically all the devices using thermo gravimetric method, belong to the group of devices of destructive control, that is, a test sample of grain in the process of measurements becomes unfit for further usage.

Non-direct methods of measurement are based on dependence of physical properties of tested object – test sample of grain on the level of its humidity. In devices, based on such methods, time of measurement does not exceed 1-5 min. [3]. In the given group, the devices using electric methods of humidity determination are widely used: conductive (resistive) devices, their operation is based on measuring of electric resistance of the sample while sending direct current across the sample, and capacitance (microwave) devices, their operation is based on considerable dependence of dielectric permittivity of grain on moisture content. This is due to abnormally high value $\boldsymbol{\varepsilon}$ of water (81 at 20 C) [4].

The Table contains characteristics of dielectric–type moisture meters, indicated by producers (suggested for sale) on the territory of the former USSR [2, 5, 6, 7, 8, 9].

Table

Main technical characteristics of dielectric – type moisture meters, available at the market of the former USSR

Denomination of the device	Country - producer	Measurement of range, %	Error of measurement/ convergence	Duration of measurement	Mass, kg	Duration of temperatures range, C
PM-300 “Kett”	Japan	1-40	±0,5		1	
PM-400 “Kett”	Japan	6-30	±0,5		1,5	
PM-600 “Kett”	Japan	1-40	±0,2...0,5/ 0,05...0,2		1,7	
Aquasearch -600 “Kett”	Japan	1-40	±0,5		1,7	
ИВЗ-М 1, ИВЗ-М l Т	Russia	8-35	±1...1,5	1	9/55	
ЦВЗ-3А	Russia	8-35	±1...2,5	2	8/10	
WILE-65	Finland	8-35	±1...1,5		0,8	0- 60
Sinar AP 6060	Sweden	1-35	±0,3	(6)		0 - 55
“KAPLA”	Russia	8-24	±0,8	(0,5)	2,5/20	
Grain Master	USA	5-40	±0,25/0,25		0,6	0- 40
ВСП-100	Russia	4-30	±0,5	1	0,3	5- 35
ВСП-6П	Russia	4-24	±0,8	1	0,5	5- 35
WILE-55	Finland	8 - 35	±0,5...1,0		0,8	
Mu1ti-Grain	USA	6- 45	±0,5		1,5	
FAUNA	Russia	6-30	±1,5			5-40
FAUNA M	Russia	6- 30	±1,0...2,0	(7)	0,33	5- 40
Farmpoint	Denmark	5- 45	±0,5		2,0	
GAC500	USA	5- 45	±0,5/0,1		5,4	0- 50
HE-50	Germany	8-35	±0,5		3,2	
Superpoint	Данія	5-45	±0,5		0,75	0- 45

Such moisture meters are composed of primary (if necessary, intermediate) measuring converter and measuring device. The accuracy of dielectric – type moisture meters depends on numerous factors, since e of tested object is a complex function of many parameters [1].

$$\boldsymbol{\varepsilon} = f\,(W,\ T,\ G,\ H,\ P,\ \ldots),$$

where *W, T, G, H, P* – humidity, temperature, granulometric composition of the ample, chemical composition of the sample, electrochemical criterion of electrode-grain boundary.

In modern dielectric – type moisture meters influence of the temperature on the result of moisture determination in greater part of cases is taken into account in the form of correction factors, which automatically or manually are introduced into final result of measurements (moisture meters of “Kett”. ЦВ 3-3А, WILE – 65/55, SINAR AP 6060, KAPLIA, GRAIN MASTER, ВПС - 100, Multi-Grain, Farmpoint, ZAC500, HE 50, Superpoint series; see Table).

Granulometric characteristics of grain are not ideal, hence of each charging the density of test sample in container-condenser is different, and, as a result, the convergence of the results reduces.

The attempts to reduce the influence of packing density in some modern moisture meters are made trying to use sample preparation – preliminary compaction of grain in the chamber of container-condenser (moisture meter KAPLIA, GRAIN MASTER, ВСП -10, WILE – 65, Farmpoint, HE 50, Superpoint series; see Table).

Chemical composition of grain test sample depends on its selective features, which are taken into consideration by means of introduction of standard curves for maximum number of agricultural crops into memory of microprocessor unit or equipping moisture meters with corresponding Tables and/or carrying out special calibration before measurement (moisture meters "Kett", ИВЗ –М1, НИВЗ –МІТ, ЦІЗЗ –3А, WILE – 55/65, Smar AP 6060, "KAPLIA", Grain Master, ВСН – 100, ВСП -6П, MULTI-GRAIN, FAUNA, FAUNA M, FARMPOINT, ZAC 500, HE-50, SUPERPOINT: see Table). Besides, chemical composition of grain is influenced by climatic condition where the crop was cultivated (soil, quantity of fertilizers, weather conditions). These factors cannot practically be forecast analytically, and can be taken into account only in some cases during preliminary calibration, using data, obtained by gravimetric method for given type (sort) of crop from the given field.

Problem setup

The information regarding moisture exchange on wall-grain boundary (electrochemical criterion of electrode-grain boundary) in container-condenser of primary measuring converter is not available in technical information from producers of dielectric-type moisture meters, that is why we can admit that the influence parameter on **ε** of test sample of grain is not taken into account.

There exist only variants in which it is suggested to carry out several measurements and reject the first obtained results and average the rest of the results [12].

It should be added to the above-mentioned that the results of measurements of **ε** depend on the relation between the quantity of free and bound moisture in tested material [10]. The existing dielectric-type moisture meters evaluate the humidity of tested sample by the value of module of its complex relative dielectric permittivity $|\dot{\varepsilon}|$, its value is determined by the formula:

$$|\dot{\varepsilon}| = \frac{C'_{meas}}{C_0},$$

where C'_{meas} - value of grain container capacitance, measured by moisture meter,

C_0 - capacitance of the empty container.

Value C'_{meas} can be calculated by the formula:

$$C'_{meas} = C_0 \times \varepsilon \sqrt{1 + tg^2\delta},$$

where ε – relative dielectric permittivity of tested material,

$tg\delta$ – tangent of the angle of dielectric losses in tested grain sample.

Hence, the result of measurement depends not only on capacitance of container filled with grain (humidity of the sample), but on the tangent of the angle of dielectric losses in tested material (humidity and mineral content of grain). Method of grain moisture measurement, suggested in [11] enables to improve the accuracy of dielectric-type moisture meters at the expense of simultaneous measurement of real and imaginary parts of complex dielectric permittivity of grain sample. But the process of water mass transfer in the volume of grain mass and on the boundary container wall-grain during measurement leads to the fact that level of connection of water molecules with the structure of grain changes and as a result during the experiment active and imaginary parts of complex dielectric permittivity do not remain constant.

The aim of the given paper – present the results of experimental researches of moisture exchange processes in container-condenser, filled with grain on the value of relative dielectric permittivity and tangent of the angle of dielectric losses of tested material sample.

Principle materials of the paper

This section contains the results of experimental research of electro physical parameters of the sample of the same grain with different levels of moisture at different conditions of experiment in sensitive element of condenser-type of moisture meter primary measuring converter.

Fig. 1 shows graphs of dependences of **ε** and *tg*δ changes in time at different moistening of grain tested sample. As it is seen from graphs, **ε** and *tg*δ change in the process of experiment more rapidly, when moisture level of grain mass is higher. For instance, during 20 minutes value of relative dielectric permittivity of grain sample increases by more than 10% as compared with initial result, and losses – more than by 25% for wet grain and only by 0.3% and 1.5% for dry grain correspondingly.

Thus, changes of ***ε*** and *tg*δ in time can be used as additional information parameter for determination of grain moisture content.

Fig. 2 shows dependences of relative dielectric permittivity and temporal losses for wet grain samples, obtained by means of one sensitive element of condenser type with walls (covers) made of different materials.

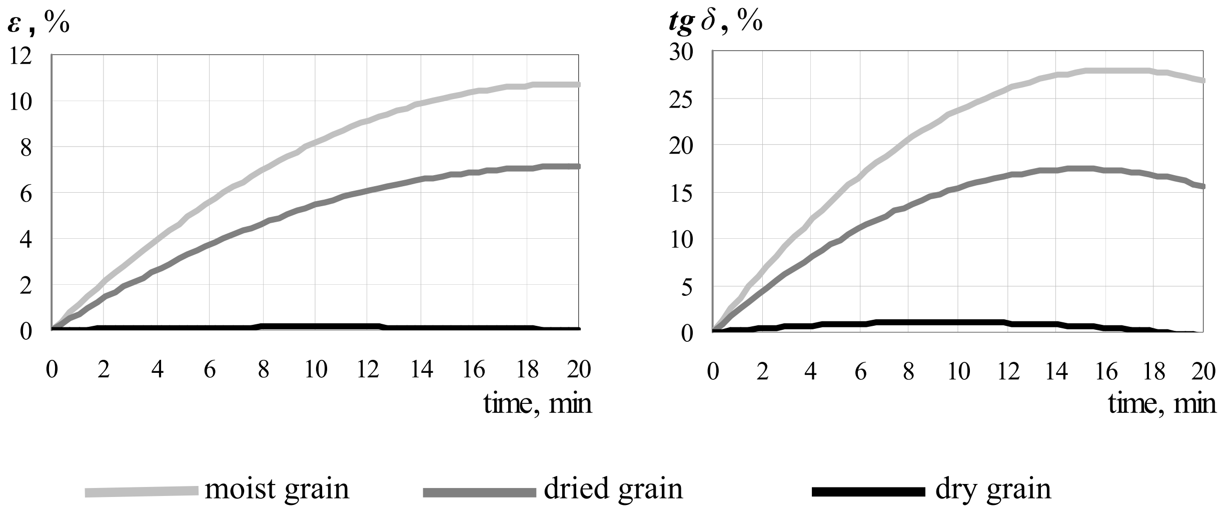

Fig. 1. Dependence in time of relative dielectric permittivity and losses of tested sample of grain with different moistening changes

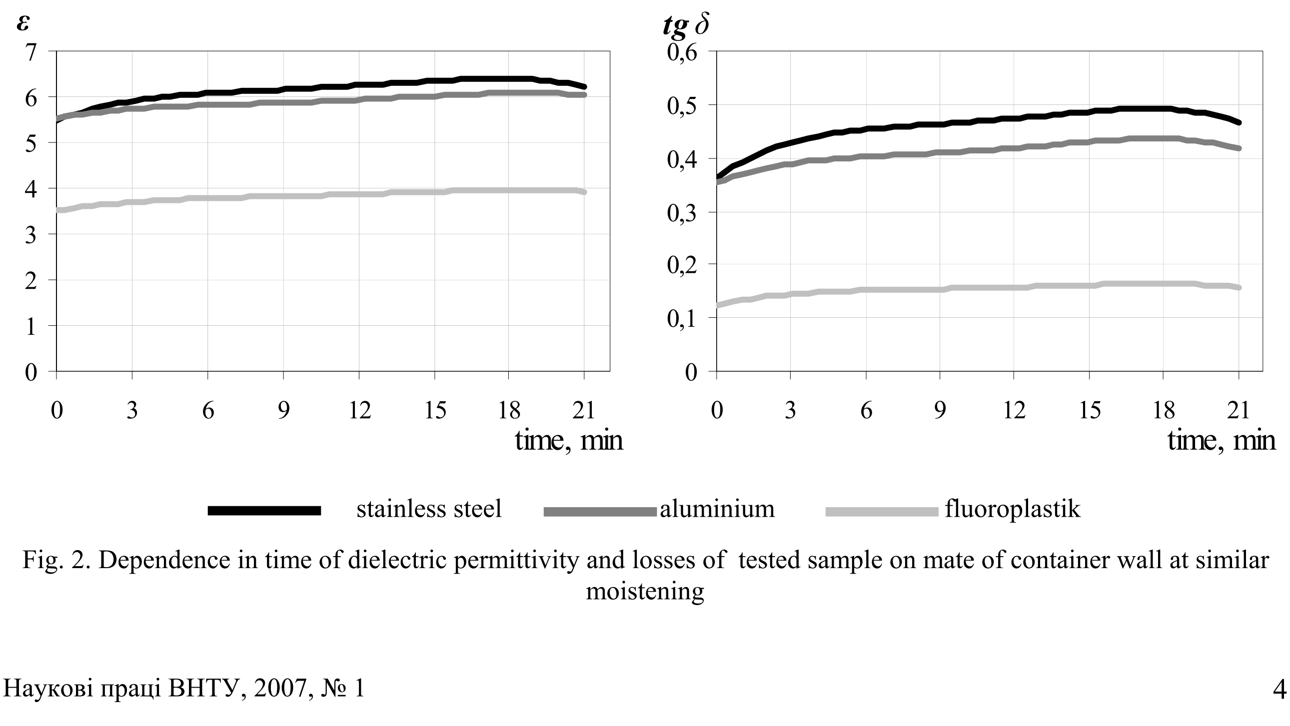

Fig. 2. Dependence in time of dielectric permittivity and losses of tested sample on mate of container wall at similar moistening

The analysis of the results obtained shows that after filling of tested sample of grain into the container of condenser type sensitive element (both regarding the volume of grain mass and on the boundary container wall – grain) processes up moisture exchange (in the direction of "bound" of moisture), take place, these processes lead to changes of values **ε** and $tg\delta$. during the experiment. Processes taking place in the volume of grain test sample after its filling in container-condenser of primary measuring converter can be explained.

When grain mass of tested sample in the container remains at rest, two factors influence water molecules coupling – "coupling" by active centres of sorption the surface of grain [10] and "release" of meniscus in the volume, formed in places of grain contact with container wall, and between each other in the volume of tested sample at the moment of grain filling in the container, all meniscus are destroyed, and the energy releases, as a result molecules of water become more bound, that leads to reduction of **ε** and $tg\delta$. When filling is completed, new state of rest begins for grain and inverse process of energy absorption from sample volume takes place that leads to reduction of coupling level between molecules of water and grain structure, as well as increase of ***ε*** and $tg\delta$. In a certain period of time, depending on ratio between free and bound moisture (moist content) in the grain, processes of release and coupling of water molecules are balanced.

The above-mentioned processes considerably influence the accuracy of dielectric-type moisture meters and are of complex character that depends on material of walls (covers) of sensitive element, and intensity of moisture exchange depends on the level of grain sample humidity.

It should be noted that moisture exchange in the volume of test sample considerably influences the results of measurements only in the devices of loading (laboratory) type, for current-type moisture meters where tested object is constantly in motion, the release of water molecules in meniscus practically does not take place, since they are constantly ruined while grain transporting in flow.

Thus, to improve the accuracy of dielectric-type moisture meters results it is necessary to take into consideration moisture exchange influence, taking place both in the volume of tested sample and on the boundary "wall of the container-grain".

Conclusions

1. Measurement accuracy of complex dielectric permittivity of tested objects of biological origin, for instance: grain crops, which are the main products of agriculture, after filling grain in the container of sensitive element of condenser type considerably decreases under the influence of moisture exchange both in volume of grain mass and on the boundary "wall-grain".

2. Process of moisture exchange is of complex character and depends on many factors, which are to be taken into account while design of dielectric-type moisture meters.

3. In order to improve the accuracy of measurement of complex dielectric permittivity of grain crops it is expedient to use as additional information parameter dependence in time of relative dielectric permittivity change on losses of tested grain sample.

REFERENCES

1. Влагомер зерна в потоке – мал золотник, да дорог. Просянык А.В., к. т. н., директор; Клабуков В.Ф., гл. конструктор АСУТП ГНПП "Эльдорадо"; Соснин К.В., аспирант НГУ г. Днепропетровск. http://dnvpeldorado.dp.ua/doc/article3.doc.

2. ТД "Автоматика" – контрольно-измерительные приборы (КИПИА), г. Смоленск, http://www. tdautomatikaru /showme.php?rasdel=5-2.

3. Влагомеры, г. Воронеж. Zernolab.ru. http://www.zernolab.ru.

4. Диэлькометрические влагомеры и гигрометры. Словарь научных терминов. Портал Естественных Наук. http://e-science.ru/index/?id=776.

5. Анализаторы влажности, г. Воронеж. Zernolab.ru. http://www.zernolab.ru/index.php?m=178&page=101.

6. Оборудование для определения влагосодержания зерна и продуктов его переработки. ЗАО "ЗЕРНОТЕХНИКА", г. Москва**.** http://www.zernotechnika.ru/equip/lab/vl_zerno.htm.

7. Влагомеры, плотномеры, вискозиметры, прочие приборы. Laborant.ru. http://www.measurement.ru/gk/

sostav/06/044.htm/

8. Влагомеры. ООО АкваСенсор. Украина. г. Харьков. http://aquasensor.com.ua/vlagomer/v_grainmaster.php.

9. Влагомер зерна, семян трав и муки. Новинка 2005 г. ООО "Агрола" , г. Москва (Институт Зерна). http://agrola.narod.ru/superpoint.htm.

10. Егоров Г. Термодинамическое взаимодействие зерна с водой //Хлебопродукты. – 2004. – №2. – С. 22–23.

11. А. С. 4775221 СССР Способ измерения влажности /Крушевский Ю.В., Куцевол М.А., Супьян В.Я. //Бюллетень. – 1992. – №9.

12. Влагомер зерна «ЭВЛАС-5». Руководство по эксплуатации САП 030.00.00.000 РЭ. СИБАГРОПРИБОР http://www.sibagropribor.ru/ru/content/doc/evlas/evlas5/manual_evlas5.pdf .

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