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Results of measurement of liquid absorption in porous materials by ultrasonic method

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Introduction

The acoustic method for investigation structure of porous materials was proposed by us in [1]. This method enables investigate changes of structure of various porous materials and products. The changes occur with deeper layers from surface of a product. The essence of the method is in measurement of amount of liquid absorbed by the material in fixed time intervals. This amount is evaluated by means of a precise measurement of changes of a liquid level in the vessel by the pulse echo method. In measurements by this method there is no necessity to take out the porous product of from the vessel. Therefore the reliability of the results obtained increases considerably. The methodics of measurements was described in [2]. The models of cylindric shape were divided into three types: the porosity is uniform in the whole volume of a product, the porosity increases linearly with an increasing deepness to the center of cylinder and the porosity increases nonlinearly with a deepness to the center of the cylinder.

In this paper we shall discuss errors of the electronic instrument within limits of the proposed block diagram.

Method

The absorption of liquid into porous bodies was investigated by the scheme described in [2]. We separated the technological part of the vessel in which the absorption was carried out from the part where we measured the level of the liquid. Such a scheme enabled us to avoid the disturbing influence to the surface stability of air bubbles ejected from the porous product. In such a construction of two vessels the error of measurements decreases $1/Dd$ times (where D is the diameter of technological vessel and d is the diameter of the vessel for a liquid level measurement). This ratio was 30 in our case.

The volume ΔV of the absorbed liquid may be evaluated by equation:

$$\Delta V_S = S \cdot \Delta l. \qquad (1)$$

Here S is the area of the liquid surface, Δl is change of the liquid level.

The significant traits of liquid absorption phenomenon are speed of absorption and its change till all holes will be filled. As we can see from Eg. 1 the dependence between changes of volume and liquid level is rectilinear if we use cylindrical vessels and area of the liquid surface does not change. We can obtain data about changes of speed of absorption from measurements of level changes. After investigation of functions

$$\frac{dl}{dt} = f_1(t) \quad \text{and} \quad \frac{d^2 l}{dt^2} = f_2(t), \qquad (2)$$

we can decide about usability of the porous material for a chosen purpose.

We investigated bread products baked in various conditions of various row materials. The ultrasonic level meter was switched in after the sample was immersed into water. The level meter allowed us to measure several times per second in 0...20 mm levels range with uncertainty ±0.02 mm.

The block-functional diagram of the ultrasonic level meter is shown in Fig.1.

For measurements two channels distance meter was used. The second measuring channel was applied as a standard channel for exact speed of sound measurements. The frequency of sensors was selected in 0.8...2 MHz range. The transmitters were exited by one half of period electric impulse. The zero cross detection circuit was used in measurement signals receiving channel. The accuracy of time intervals' measurement was equal to the accuracy of the phase method. The noted time interval that is proportional to the measured distance was filled by 100 MHz marks. These marks were counted by a counter and processed mathematically by the processor Intel 8031. The processor performs the primary processing of measurement information (elimination of changes of speed of ultrasound, averaging of results, etc.). The meter may be connected to PC through the interface RS485. The meter also has numerical indicators showing two rows four-figure results.

The achieved uncertainty of 0.02 mm of a liquid level evaluated in liquid volume is 0.4 mm^2. It arises because the instabilities of electronic part of a level meter. The reasons of instabilities are noises in electric circuits and instability of the threshold level of the electronic comparator. Therefore the end of the signal delay time interval fluctuates. This instability was reduced by averaging the results of measurements.

The errors arising due to changes of temperature, composition, humidity and pressure of air in the acoustic measurement channel were eliminated by including the additional calibrated length channel for measurement of speed of sound. The influence of vibrations and waves in air was avoided by using a massive bottom and cover for protection of a acoustic part of the level meter.

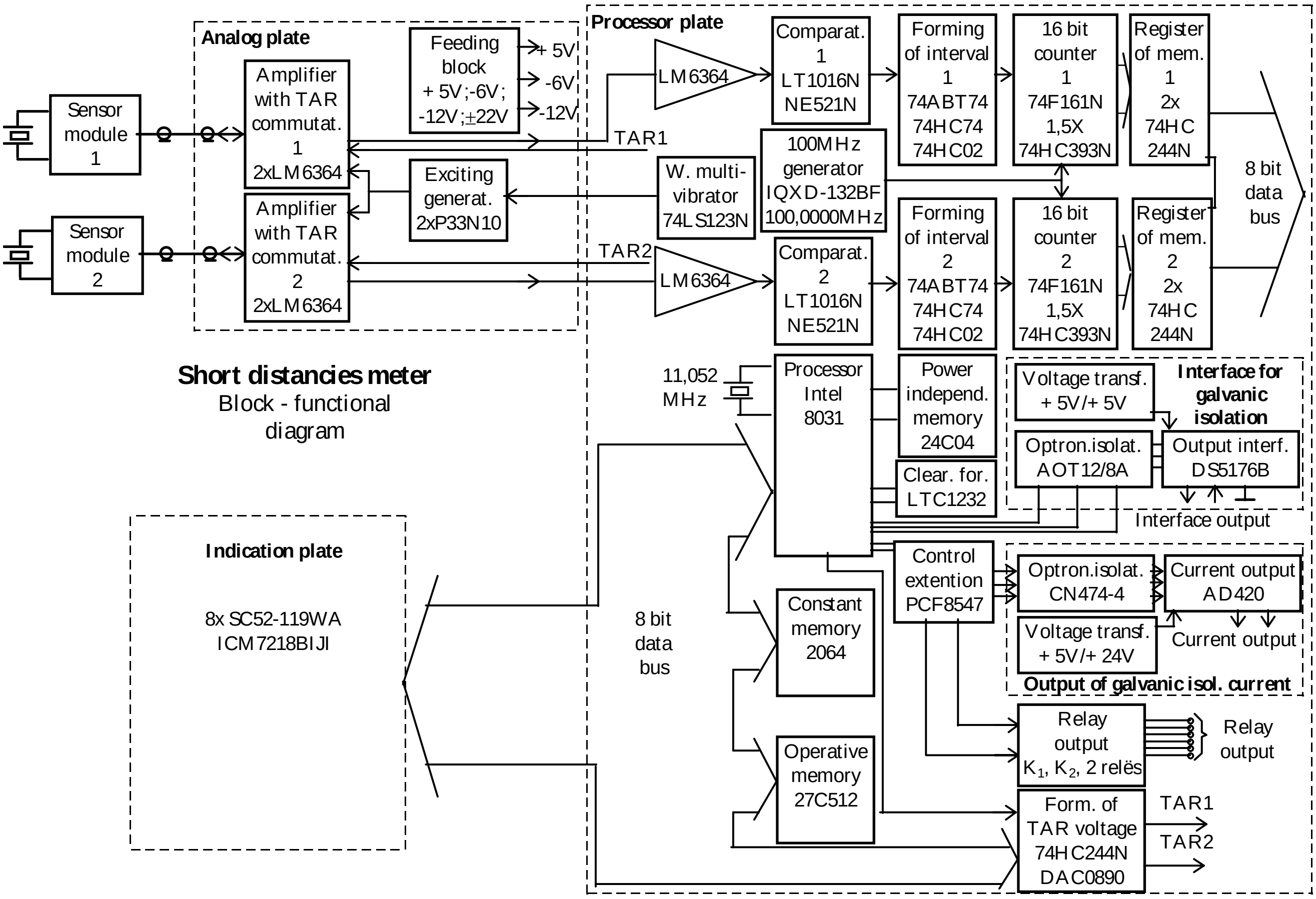
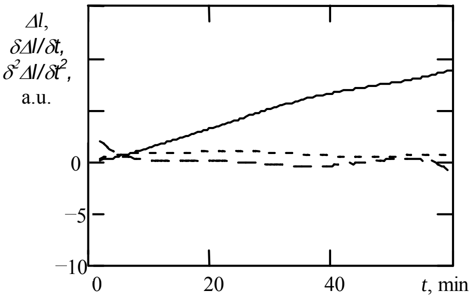


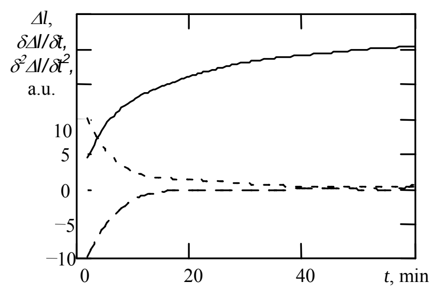
Fig.1. **The block diagram of ultrasonic the level meter**

Experimental technique

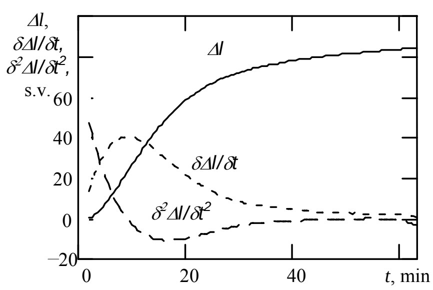
Various examples of baked products were investigated. They were in the form similar to cylinder. The curves of changes of the liquid level versus time were obtained for every product. The processing of these curves was carried out by calculating the derivatives of the first and the second row against time. The comparison of results enabled us to divide the curves into three groups. The baked products that showed approximately uniform absorption speed in the whole time interval formed one group. The second group of products was that showed the decreasing absorption speed. The third group of products was that showed change of sign of the second derivative in the first stage of absorption process. The examples of curves of these groups are shown in Fig. 2.



a)



b)



c)

Fig. 2. **Typical dependencies of absorption dynamics versus time in various groups of baked products. The solid line is a result of liquid level measurements, the dotted line is the first derivative and the dashed line is the second derivative of the absorbed amount of liquid versus time**

In Fig. 2a the curve reflects the uniform structure of flour baked ware. The surface film of the product is very thin and the intrisinc structure is uniform what is seen from constant liquid absorption. Fig. 2b illustrates absorption of a liquid into flour baked product that contains a surface layer with a small porosity structure and coarse defects of porosity in the undersurface layer. Liquid penetrates with a high speed the undersurface vacancies into the product and than the speed of penetration falls in the layer of a smaller porosity and later becomes constant in the zone of a uniform porosity. The curve in Fig. 2c illustrates liquid penetration into a flour baked ware with a surface film without defects. The decreasing of speed of absorption till a constant shows an increasing porosity with a deepness and an uniform porosity in the central part of the product.

Thus on changes of speed and acceleration of absorption we can decide about changes of porosity of the product and at the same time decide about a quality of a product. The curves in Fig. 2a, c are examples of the products of a high quality.

Conclusions

The level meter of short distances having the uncertainty of 0.02 mm enabled us to investigate in short time the water absorption dynamics of the row of products baked from different raw materials. The processing of obtained results was carried out by calculating the absorbed liquid volume derivatives of the first and the second row against time. It was determined that the most informative is the initial stage of absorption process. The baked products were divided into three groups according to the shape of curves in the initial part. The additional investigations showed the relationship between these groups and the taste properties of baked products.

This method for evaluation of porosity by the measurements of speed of absorption may be useful in creation of new technologies for production of various porous substances, because enables evaluate parameters of porosity and its changes objectively.

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Poringų medžiagų skysčių sugėrimo matavimas ultragarsiniu metodu

Reziumė

Mažų atstumų lygio matuokliu su 0,02 mm neapibrėžtimi greitai ištirta kepinių, pagamintų iš skirtingos žaliavos, vandens sugėrimo dinamika. Tiriant gautus rezultatus įvertintos išmatuotų kreivių pirmos ir antros eilės išvestinės pagal laiką. Nustatyta, kad informatyviausia yra pradinė kreivės dalis. Pagal šių kreivių pradinės dalies kitimo pobūdį kepiniai buvo suskirstyti į tris grupes. Papildomi tyrimai parodė šių grupių sąryšį su kepinių skoninėmis savybėmis.

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