

THE CONTROL OF MOISTURE OF ROCKS BY METHODS OF MICROWAVE AQUAMETRY

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ABSTRACT. Laboratory and on-line resonator moisture meters have been developed for application in mining. Metrologic characteristics of developed devices have been studied.. Industrial testing was carried out on a number of rock and chemical materials. The applicability of linear model is shown at the production of material with the given dielectric properties.

Keywords: moisture, moisture meter, mining

1. INTRODUCTION

The monitoring of moisture of rock concentrate in the process of dressing and drying is one of important conditions in the development of automatic system for the control by mining technology. A crushing and flotation are the most famous methods of rock dressing. After flotation the drying of concentrate is necessary. Usually the moisture of drying rock concentrate is 0.1-2 %. The multiplicity of the technology processes and the conditions of measurements causes the necessary of using the microwave sensors differing by work frequencies and construction. In this connection the problem of analysis of data obtained at different measurement conditions of sensor arises. The direct electrodynamic calculation of sensor parameters in the medium with dielectric losses is possible only in separate cases.

Nevertheless the dielectric spectra of the most of rock are good studied in the wide frequency range. [1 -2]. The problem of sensor calibration can be solved by using the model material with known dielectric characteristics and mechanical properties closed to properties of rock concentrate.

This paper is devoted to the problem of moisture measurement of rock at the process of crushing and flotation by microwave sensors.

2. SELECTION AND INVESTIGATION OF A MODEL MATERIAL

A model material should satisfy the following requirements:

1. Its dielectric characteristics should be well enough described on the basis of one from known formulae for mixture.
2. The material should be well known and abundant.
3. Its mechanical properties should be similar to the same of rock concentrate.

Quartz sand has been chosen as such a material with density of 1.46 g/sm., to which a dielectric permittivity of 2.2 corresponds.

The comparison of calculated dielectric characteristics of moisture sand with experimental data obtained is carried out.

In calculation the attenuation coefficient α and coefficient of propagation of electromagnetic wave β in wet materials are the linear superposition of corresponding coefficients for each component (linear model):

$$\alpha = \sum_i v_i \alpha_i, \quad \beta = \sum_i v_i \beta_i,$$

where v_i is a volume content of i -component.
Using known relations [3]

$$\alpha = \frac{\pi}{\lambda} \frac{E''}{\sqrt{E'}}, \quad \beta = \frac{2\pi}{\lambda} \sqrt{E'},$$

where λ is a wavelength, $E = E' - iE''$ is a complex dielectric permittivity, we can obtain next expressions for 3 - component mixture (material+water+air):

$$E'' = \frac{E''_w}{\sqrt{E'_w}} W \rho \sqrt{E'},$$

$$\sqrt{E'} = W \rho (\sqrt{E'_w} - 1) + (\sqrt{E'_d} - 1) \frac{\rho}{\rho_d} (1 - W) + 1,$$

where W is a moisture content, ρ is a density of moisture material, $E_w = E'_w - iE''_w$ is a dielectric permittivity of water, ρ_d is a density of dry material, E'_d is a real part of relative permittivity of dry material with density ρ_d .

The measurements were carried out in a rectangular wave guide 23*10 mm at 10.5 GHz and 18 GHz frequency, sample mass was 30 g, temperature was 20 C°. The experimental values of E were calculated from the measured values of attenuation coefficient and reflectivity of moisture sand.

The comparison of calculated and experimental data for E shows that the linear approximation is correct (Fig.1 and Fig.2). The difference does not exceed 10%. This allows to prepare a model material (sand +reference liquid, for example, water) with dielectric properties closed to characteristics of rock concentrate and other materials for which the sensors are developed.

The limited application of the pointed method for conductive materials should be noted (Fig.3 and Fig.4). The significant difference of calculated data obtained with linear theory from experimental one is observed.

3.RESULTS AND DISCUSSION

The offered method of production of model materials was applied at development of rectangular resonator sensor for laboratory moisture meter and open resonator for on-line moisture meter. A sample was placed between minimum of electric and magnetic intensity in laboratory moisture meter. At on-line measurements a material was moved on conveyer belt and was in contact with open resonator.

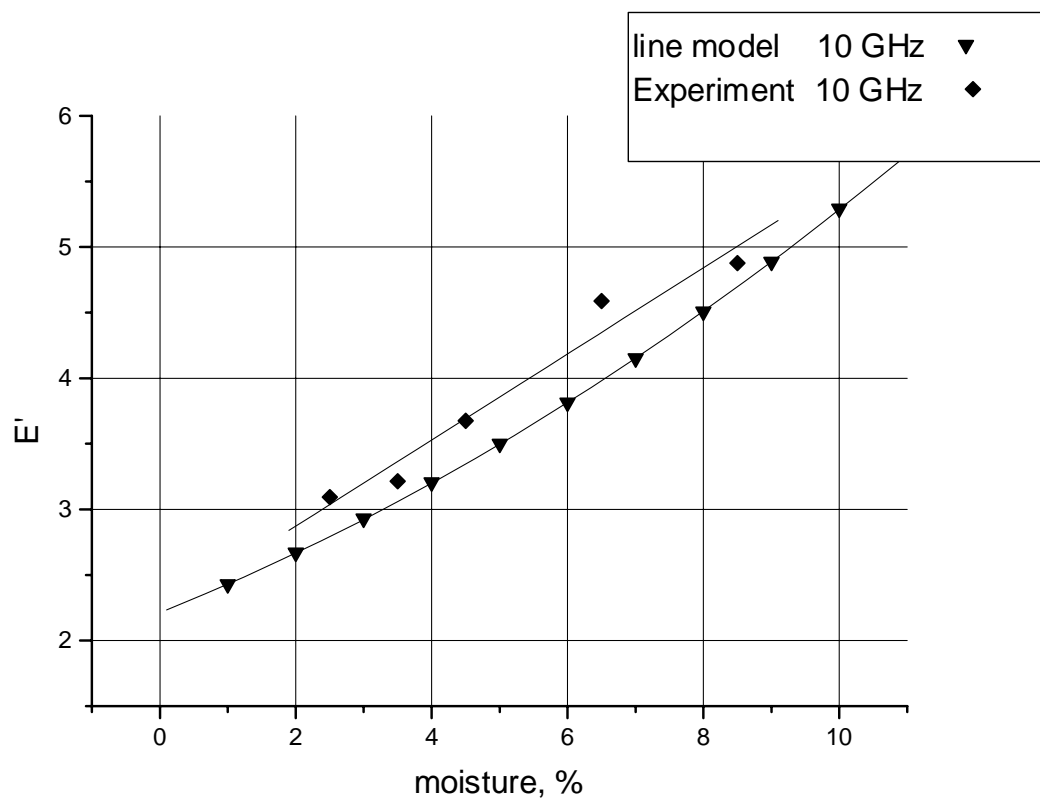


Fig.1. Dependence E' of moisture sand on moisture .

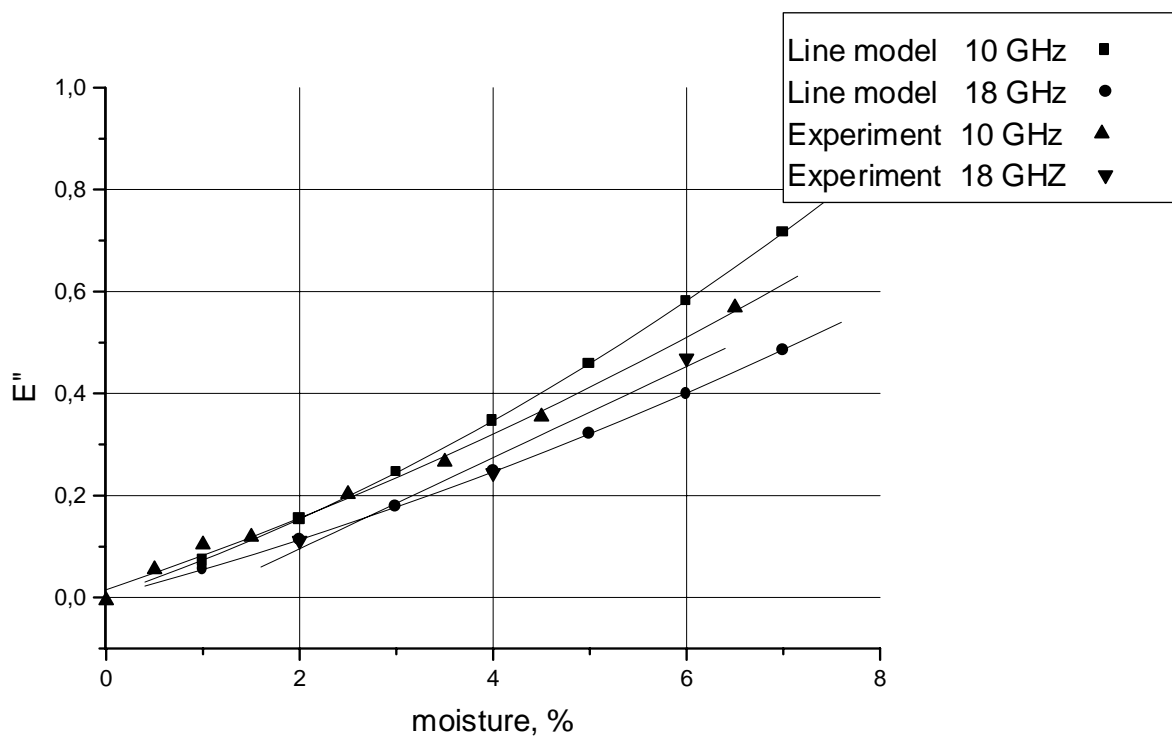


Fig.2. Dependence of E'' moisture sand on moisture .

The results of moisture meter testing in industrial conditions for the measurement of bauxite rock concentrate moisture are shown on Fig.5. The same date for on-line resonator moisture meter and for apatit and NaCl are shown on Fig.6 and 7. The sensor opportunities for very low moisture (0 - 1 %) were tested at moisture measurement of carbamid and sulfat amonia in industrial conditions.

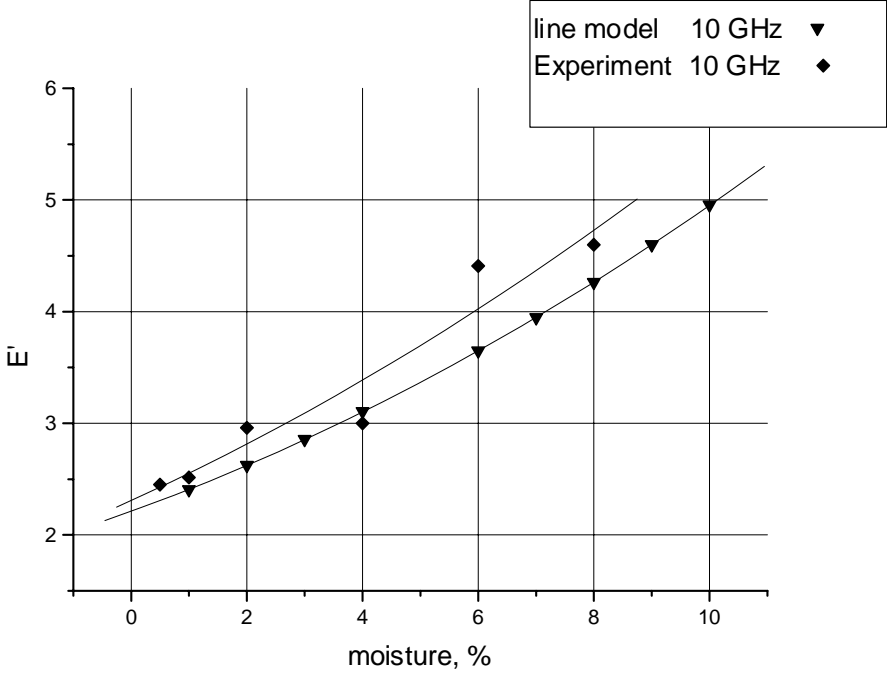


Fig.3. Dependence of E' moisture KCl on moisture .

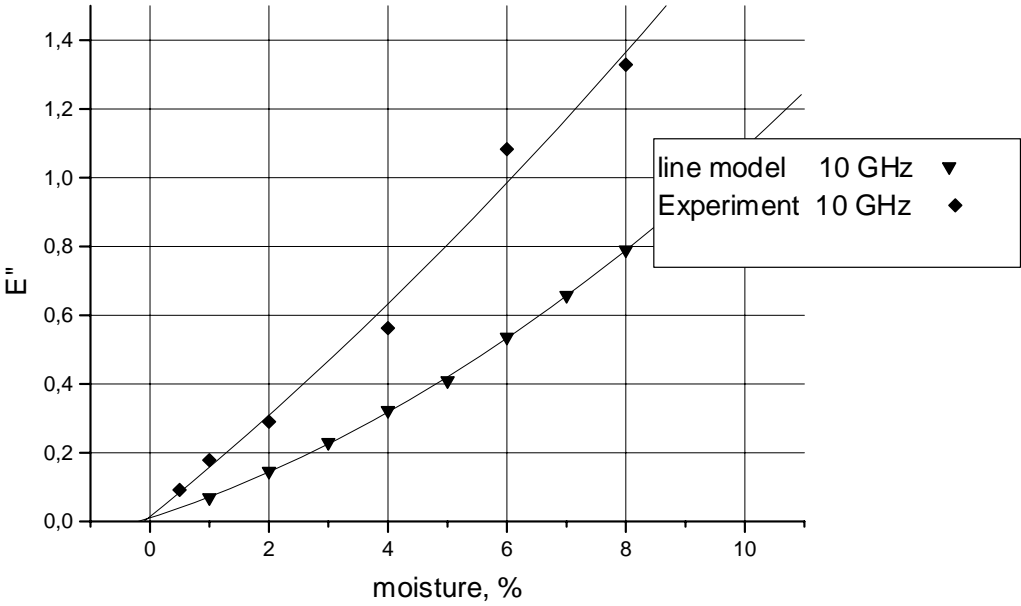


Fig.4. Dependence of E'' moisture KCl on moisture .

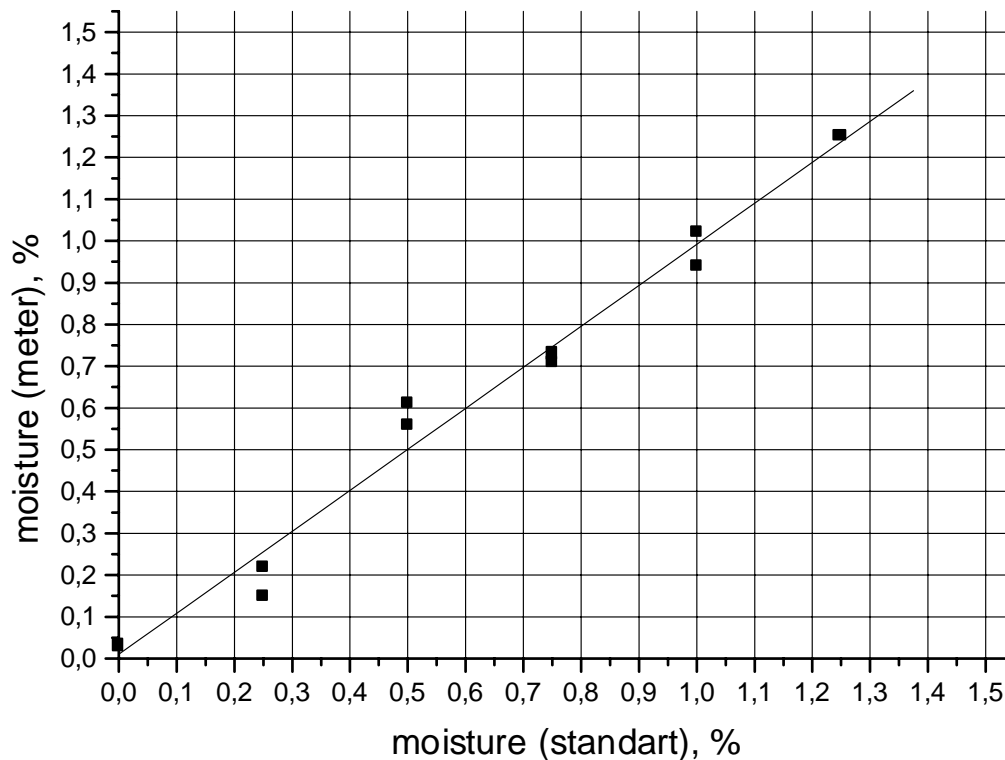


Fig.5. Dependence of moisture meter data of boxite rocks on moisture of standart method (oven).

The results (R is a correlation coefficient, SD is standart deviation) of statistical analysis of these tests are shown in Tab. It is easy to see that 2SD does not exceed 0.15 % for all material studied at sufficiently high correlation coefficient. It should be noted that the metrologic characteristics of moisture meter developed exceed significantly the requirements of mining and chemical branch. So our moisture meters can be used in a number of other applications, for example, in pharmacology.

The results of the statistical analyse of moisture meter tests

moisture meter	material	SD, %	R
lab.	bauxite rocks	0.064	0.99
on-line	apatit	0.022	0.998
on-line	NaCl	0.0041	0.998
on-line	sulfat amonia	0.01	0.997
on-line	carbamid	0.011	0.99

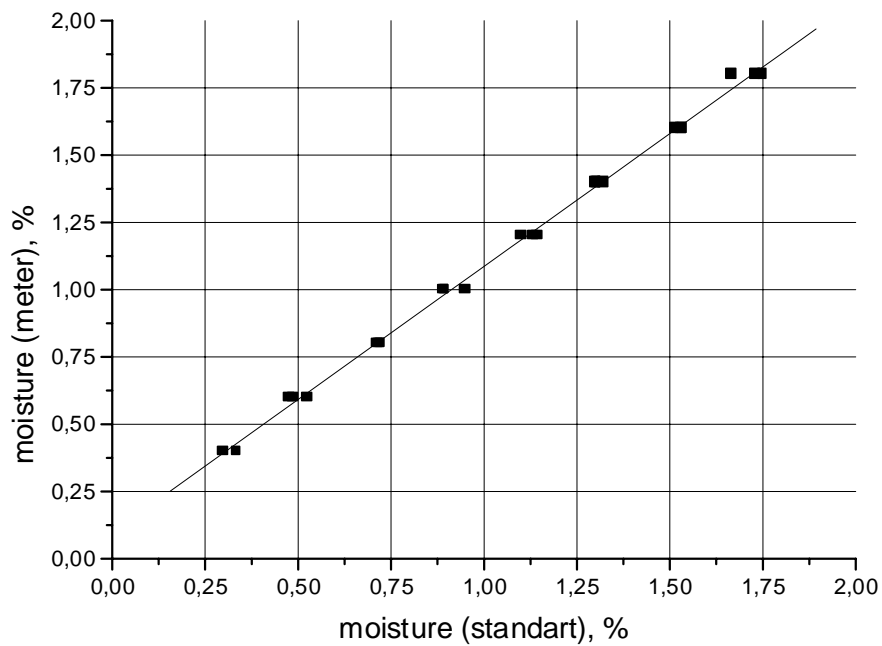


Fig.6. Dependence of moisture meter data of apatit concentrate on moisture of standart method (oven).

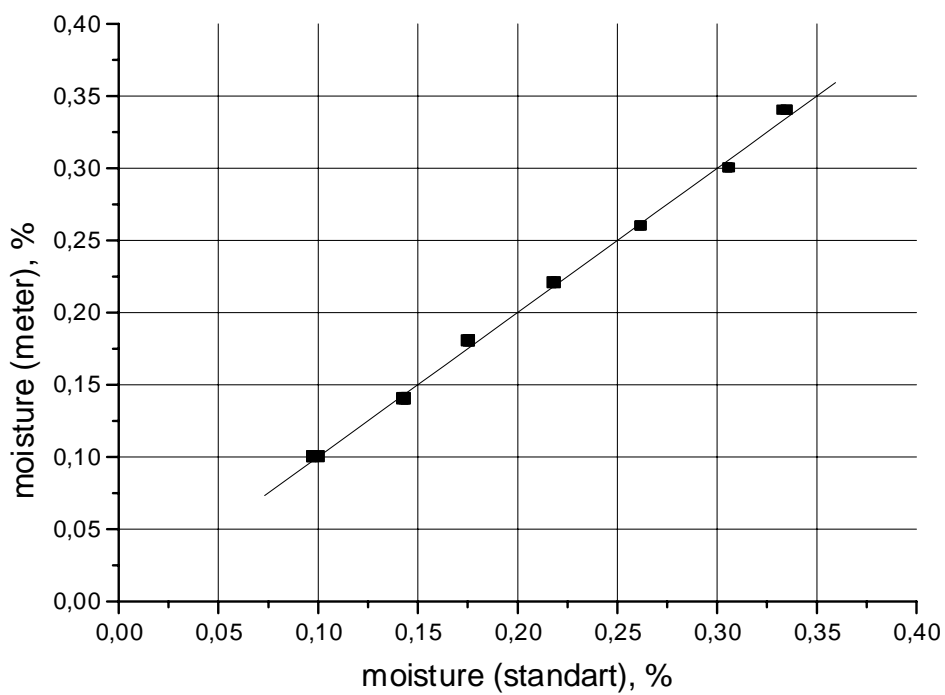


Fig.7. Dependence of moisture meter data of NaCl on moisture of standart method (oven).

A few tens of moisture meters pointed constructions (Fig.8) are produced and successfully work on different enterprises of Russia.

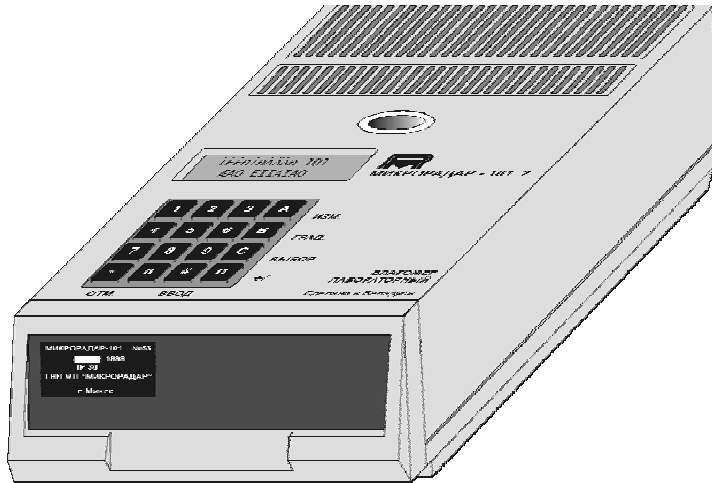


Fig.8 The outward of laboratory and on-line moisture meters.

4.CONCLUSION

The considered technique of estimation of microwave moisture sensor characteristics with use of model material gives the opportunity of the comparison of data obtained in different conditions.

The use of the linear model allows to prepare the materials with given dielectric characteristics without carrying out labour - intensive preliminary experiments.

The developed laboratory and on-line moisture meters are characterized with high metrological parameters.

We have also determined limits of the accuracy of microwave methods for concrete applications. All data are confirmed experimentally at the enterprises of Russia.

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