Analysis of Microwave Sensors in Various Industries

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Abstract—
Moisture content in products/substances can reduce the quality of the substance. Moisture occurs nearly in all substances and greatly affects the properties of the host material, forming critical aspects of cost and product quality. It also reduces the life time of the product The accurate measurement of moisture requires the skill and time because of its inherent characteristic of water molecules to coexist with the moist materials through absorption and adsorption. Moisture content of most solids and liquids needs to be monitored and controlled because of the effect of moisture on product quality, storage conditions, product life, product weight and hence economic benefit. This can be done using microwave moisture measurement technique. In this paper we discuss about how to measure the moisture content present in various industries such as spice, sugarcane, food, rubber.

Keywords—absorption, adsorption, microwave, moisture, product, watermolecules.

I. INTRODUCTION

Moisture content in products/substances is one of the key quality physical parameters in many industries. Moisture occurs nearly in all substances and greatly affects the properties of the host material, forming critical aspects of cost and product quality. The accurate measurement of moisture requires the skill and time because of its inherent characteristic of water molecules to coexist with the moist materials through absorption and adsorption. Moisture content of most solids and liquids needs to be monitored and controlled because of the effect of moisture on product quality, storage conditions, product life, product weight and hence economic benefits.

Moisture measurement is important in many raw materials, foods, and agricultural products and in civil engineering. This contributes to the guarantee of quantity and to reduce losses in trade and storage. During the drying process, moisture measurement can help to maintain the level of moisture required in the material. The weight increase due to higher moisture content will also decrease the financial profit. Moisture content in solids is normally specified as percentage by weight[1]. In liquids, water content is specified as percentage by weight or volume.

Percentage of moisture with respect of dry weight

$$M_d = (W_m*100)/W_d \quad [1]$$

Percentage of moisture with respect of wet weight

$$M_W = (W_m*100)/(W_d+ W_m) \quad [2]$$

Where W_d is weight of dry material and W_m is weight of water.

Moisture measurement is very important in various industries such as pulp and paper, sugar, rubber and spice industries. In pulp and paper, with too much moisture, the product is wasted and will send profits down the drain, whereas over drying will burn up the profit[3]. In sugar industries moisture measurement is important because the concentration of juice relates to the sugar content[4] . In rubber industry concentration of latex relates with the dry rubber content. The cost of the rubber directly depends on the dry rubber content. Moisture content in spices is important in determining the quality of the spice [2].

II. MOISTURE MEASUREMENT METHODS

Conventional methods such as gravimetric method, Karl- Fischer titration, electrical methods, nuclear and infrared absorption method are used to measure moisture content[3]. Among this microwave has many advantage than others.

III. MICROWAVE TECHNIQUE:

Microwave techniques are attractive because at these frequencies the electrical energy is strongly absorbed by water because of the dipolar character of water molecules, and the effect of ionic conductivity is negligible[9]. Microwave techniques provides the advantages over other methods, such as low cost, good penetration in non-metallic materials, good resolution, non- invasive, pollution free, bulk information etc. Moisture content has been related to dielectric properties[8]. The advantage of using this technique over the traditional oven dried methods is that permittivity can be measured in near real time. This paper discussed about various microwave sensors used in various industries.

IV.MOISTURE MEASUREMENT IN VARIOUS INDUSTRIES USING MICROWAVE SENSORS:

When microwaves are directed towards a material, part of the energy is reflected, part is transmitted through the surface and out of this later quantity part of it is absorbed. The proportions of energy, which fall in to these microwave ranges, have been defined in terms of the dielectric properties.

$$\varepsilon^* = \varepsilon' - j\varepsilon'' \qquad [3]$$

Where ε' = dielectric constant,

and ε'' = dielectric loss factor.

The dielectric properties of a material are represented by a complex quantity know as permittivity. The real part of permittivity (ε') is a measure of the energy stored and is called the dielectric constant[8]. The imaginary part of permittivity (ε'') is a measure of the energy loss and is called the loss factor.

V. MOISTURE MEASUREMENT IN PULP AND PAPER INDUSTRY

Bulk moisture in paper during production cannot be measured by using conventional methods such as gravimetric, Karl-Fischer titration and conductivity method. To solve this problem the microwave resonator sensor has been used. It has high accuracy and high sensitivity. This has been designed using the principle of resonant cavities. When a sample of wet paper is introduced in between the cavities, the resonant peak at the measuring mode would be shifted to another frequency. At the same time, the resonant peak at the reference mode does not shift. Hence the difference between the two resonant peaks can be measured. Bulk moisture can however, be measured by using cavity resonators

By measuring the resonant frequency, it is possible to calculate the permittivity constant of the material. The permittivity is proportional to the amount of water in paper sample and its moisture content value can be directly derived from the frequency shift measured. By using this technique, up to 80% moisture content can be measured.

VI. ESTIMATION OF SUGAR CONTENT IN SUGAR CANE

Estimation of sugar content in sugar cane is important task in sugar refineries as well as in food industries because of continuous evolution during fermentation process. Early estimation of sugar content in cane juice also enables fixing the price of canes for procurement from the fields[6]. So it is felt that a quick method should be developed for estimating the sugar content in the field before cane harvesting and delivery to sugar factories would be highly useful. Sugar cane juice contains a large amount of water (80%) and organic matter (20%). The sugar content in sugar cane juice is measured by calculating the dielectric constant of the cane juice by using liquid dielectric cell and is shown in Figure.1. The concentration of cane juice has been found to decrease with increasing dielectric constant, and the sugar content is measured from the dielectric constant.

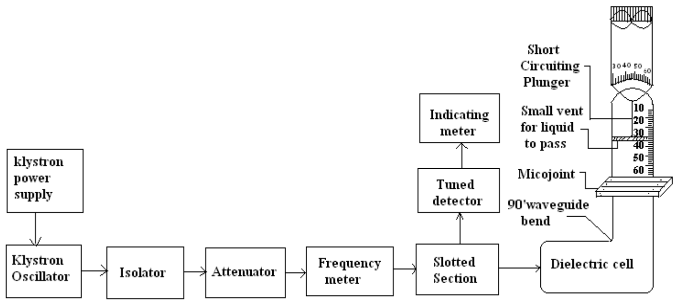

Fig.1.Measurement of sugar content in cane juice Dielectric liquid cell

VII. DETERMINATION OF DRY RUBBER CONTENT IN RUBBER LATEX

One of the industrial applications of microwave is in the detection of Dry Rubber Content in the natural latex obtained from Hevea brasiliensis. The cost of the rubber directly depends on the Dry Rubber Content (DRC)[10],[11]. At present, conventional method consumes a large amount of time and does not remove the allergy causing proteins from natural rubber. Therefore, the proposed electronic method of detection of Dry Rubber Content in the present scenario is the most advantageous, since rubber has high economic importance and industrial demand. The determination of Dry Rubber Content in the natural latex obtained from Hevea Brasiliensis is carried out by microwave techniques. By using the above liquid dielectric cell shown in figure.1, DRC is calculated indirectly by measuring the dielectric constant. This method involves in finding of a relation between the known value of DRC samples and its respective dielectric constants, with varying the moisture (water) content of various samples and the dielectric constant is found. The dielectric constant increases with increasing moisture content.

VIII. DETERMINATION OF MOISTURE IN SPICE INDUSTRIES

In spice industries resistance type and RF capacitance type moisture meters are commonly being used to measure the moisture content. The transmission line method is best for solid materials that can be precisely machined to fit inside a coaxial or waveguide airline. Although it is more accurate than the coaxial probe technique, it is still somewhat limited in resolution for low loss materials.

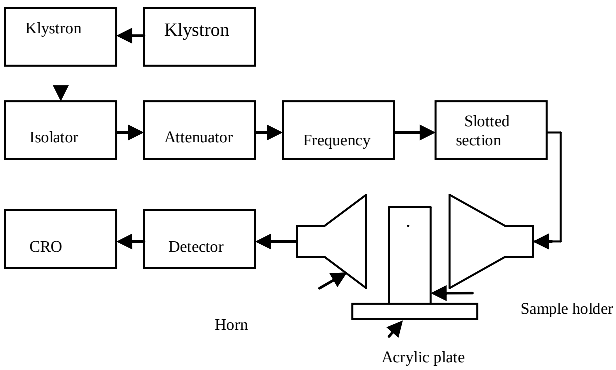

Figure.2 Measurement of moisture in spices using free space method

The resonant cavity system consists of a resonant cavity connected between the source and detector. The dielectric properties is calculated from the transmission response of the cavity, measured empty and then with the sample. The bulk moisture content in paper industries has been measured by using microwave resonator. The resonator technique has been used. This method has the advantage of low cost but spice samples are crushed and wasted. The RF capacitance type moisture meters measure the capacitance of the samples between the two electrodes, thus sensing the dielectric constant of spice. The spice moisture meter has been developed to measure the dielectric properties of spices such as cardamom and pepper with various moisture contents by calculating the attenuation and phase shift.

Free–space technique is shown in fig 2.It is also grouped under non-destructive and contact-less measuring methods. In our work, this technique has been used for measurement of moisture in the spice industry. In this technique, a sample is placed between a transmitting antenna and a receiving antenna and the attenuation and phase shift of the signal are measured, the results of which can be used to translate the material dielectric properties. Accurate measurement of the permittivity over a wide range of frequencies are achieved by free space techniques.

IX. RESULTS

The moisture content as applicable in various industries has been computed using microwaves with different methods. In the case of paper industry, the relationship between permittivity and frequency shift has been utilised.. Since the permittivity is proportional to the frequency shift, the moisture content value can be directly derived from the frequency shift measured.

In the sugar industry, the estimation of sugar content in sugar cane has been done by using liquid dielectric cell.. The concentration of cane juice has been found to decrease with increasing dielectric constant, and the sugar content is measured from the dielectric constant.

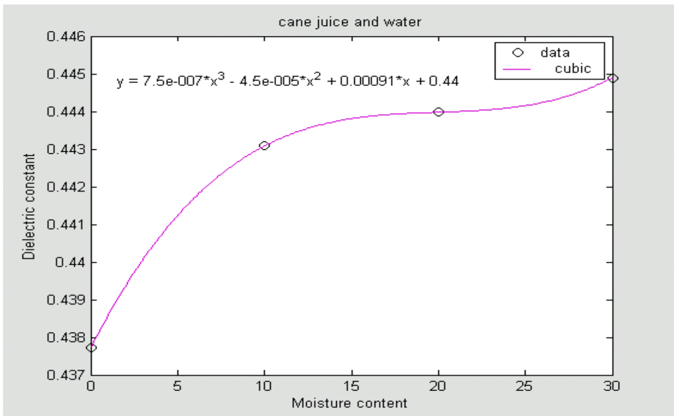

Figure.3 Moisture content vs Dielectric constant

In the rubber industry, the measurement of dry rubber content in rubber latex has been found using liquid dielectric cell. This method involves in finding of a relation between the known value of DRC samples and its respective dielectric constants, with varying the moisture (water) content of various samples and the dielectric constant is found. The dielectric constant increases with increasing moisture content. Fig 4 shows that DRC vs Dielectric constant.

In spice industry the dielectric constant and loss factor has found as a function of attenuation and phase shift respectively. Both the dielectric constant and loss factor of cardamom increased with moisture content an is shown in fig.5, The attenuation and phase shift also varies with moisture content. The output power is decreased with increased moisture content is shown in figure 6.

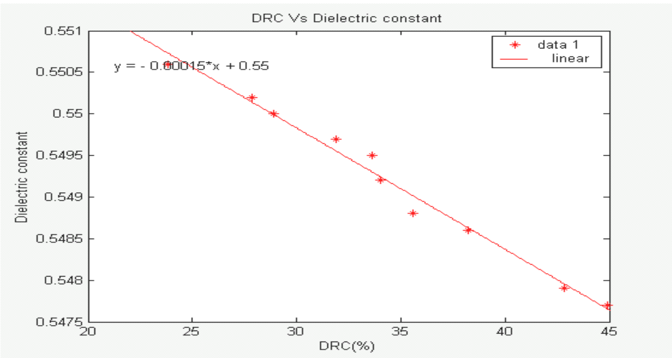

Figure.4 DRC vs Dielectric constant

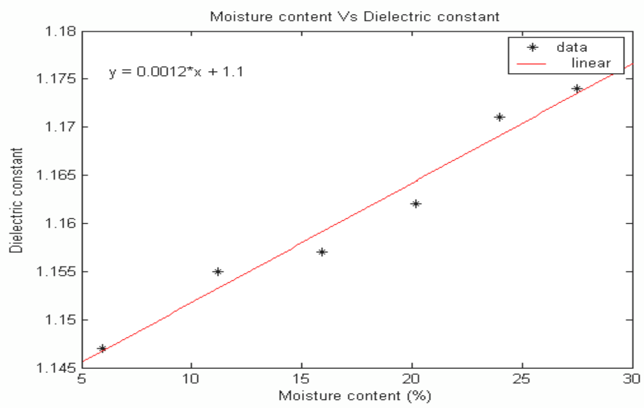

Figure.5 Moisture Content vs Dielectric Constant

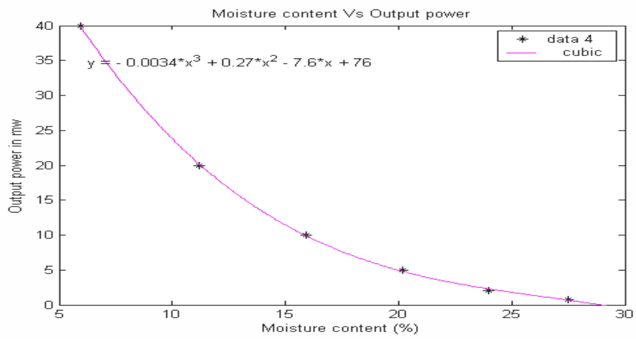

Figure.6 Moisture Content vs output power

X. CONCLUSIONS:

In this paper, investigates the study of moisture measurements using microwaves having relevance in some selected industries such as pulp and paper, sugar, rubber and spice industries. The estimation of sugar content in sugarcane is measured by measuring the dielectric constant of the sugarcane juice using liquid dielectric cell. The Dry Rubber content in rubber latex is also calculated by measuring the dielectric constant of the rubber latex. The moisture content in spice is calculated by measuring the dielectric properties of spices

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