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Performance evaluation of digital grain moisture analyser for Indian wheat

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This study presents an inexpensive and portable micro-controller based digital grain moisture analyser (DGMA) for Indian wheat. A prediction model has been devised to readily calculate and display moisture (%) on digital readout. A good co-relation was found between moisture values of Indian wheat compared with moisture values for same grain with standard dry oven method. High values of coefficient of correlation under all plotted graphs indicate high accuracy of DGMA.

Keywords: Calibration curve, Coefficient of correlation, Digital grain moisture analyser, Dry oven technique, Linear regression studies

Introduction

Moisture content of grains and oilseeds is extremely important from stand point of harvesting storage[1], handling, processing and marketing. Dry grain is more prone to handling damage and kernel breakage than grain kept at optimum moisture[2]. Moisture content is critical in determining quality of product and processing behavior, so grain must be conditioned to specified moisture levels if it is not already within the desired range[3]. Microorganisms can spoil grains if stored at higher moisture contents for prevailing environment[4]. Several methods that are used to measure moisture content suffer from disadvantages[5-8]. This study presents development of an inexpensive and portable microcontroller (MC) based digital grain moisture analyser (DGMA) for Indian wheat. Behavior of dielectric cell has been studied for Indian wheat grain at various moisture levels.

Experimental Section

Principle of Capacitance Variation

Dielectric properties of grains are used in electrical sensing of moisture content[9]. Therefore, capacitance sensing instrument, in which grain samples influence capacitance of a sample holder, can be used for rapid moisture content measurement[10]. In reported studies[11-15], developed models predict dielectric constant of several kinds of cereal grains and soybeans as functions of frequency, moisture content and bulk density at 24°C. A composite model for cereal grains provides an estimate for both dielectric constant and loss factor[16]. Dielectric constant (ε') and loss factor (ε''), respectively, are real and imaginary parts of relative complex permittivity, $\varepsilon = \varepsilon' - j\varepsilon''$. Loss tangent [tan$\delta$ (δ being loss angle of dielectric)], and ac conductivity (σ) are often used, and can be calculated as $\tan\delta=\varepsilon''/\varepsilon'$ and $\sigma=\omega\varepsilon_o\varepsilon''$, where $\omega=2\pi f$ is angular frequency and ε_o is permittivity of free space.

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Dielectric Cell

A capacitor comprises of two oppositely charged conductive plates separated by an insulator (dielectric). Capacitance (charge stored by capacitor) of sensor changes with moisture content of hygroscopic dielectric layer. Resultant change in capacitance is measured by an oscillator, a capacitance sensing sub circuit and a detector. Variation of dielectric constant of hygroscopic material is almost linear over a limited period but useful for a range of 3-28% moisture content. Dielectric cell is designed in the form of concentric cylindrical capacitor (CCC) (Fig. 1), which gives operational ease, highest electric field, uniform field density over a length, and less fringing field if proper ratio between length and cylindrical diameters are maintained. For a simple plate capacitor, capacitance is $C = (KA)/d$, where, C is

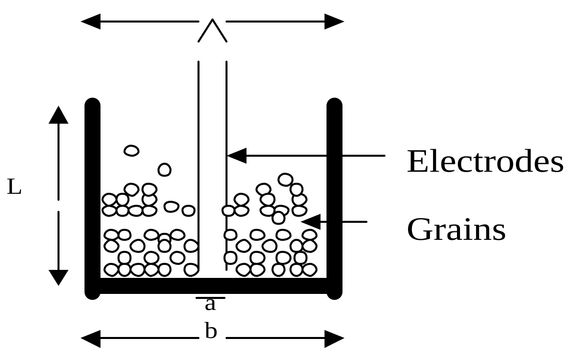

Fig. 1—Schematic diagram of cylindrical sensor

capacitance, A is surface area, K is dielectric constant, and d is distance between plates. Since capacitor is a physical device, a particular capacitor will have a constant plate surface area and distance between plates. Changes in capacitance are then dependent only on dielectric properties of dielectric. Capacitance for a simple CCC is given as $C = (2 \Pi \varepsilon L)/ \log_{10}(b/a)$, where, ε is dielectric constant of medium filled in space, L is length of cylinder, b is inner radius of outer cylinder and a is outer radius of inner cylinder. For system, capacitance is given as

$$C = (2\pi\varepsilon_o\varepsilon_L) / 2.3 \ln (b/a) \text{ Farads/m} \quad \ldots(1)$$

where, ε_o is absolute permittivity ($8.854 * 10^{-12}$ Farads/m). In Eq. (1), all parameters are constant except ε.

Working of Dielectric Cell

When sample is poured in cylinder (sensing chamber), a change occurred in capacitance of concentric cylindrical sensor is converted into equivalent milli volts (mV). Various types of grains having variation in moisture content gives corresponding variation in mV, which are further converted into digital form using analog to digital converter, used further by MC unit for necessary data processing. MC unit fetches information already stored in memory along with necessary mathematical manipulation required. It also takes into consideration the calibration, which is also stored in memory. Various prediction models prepared systematically for various types of grains are also stored in the memory taking into account type, size and moisture range of grains. Once MC receives data duly processed by ADC, it performs calculations as per the formula, calibration technique, prediction model (already stored in memory) and finally displays % moisture and temperature on display unit (Fig. 2). While performing measurements, user can select various grains using UP and DOWN keys from keyboard. For repeat measurement or new grain measurement, user uses REPEAT key. For more precise measurement, user should repeat measurement 4-5 times and take a mean as final moisture (%).

Results and Discussion

Nature of relationship between capacitance and measured moisture is nearly linear (Fig. 3). Correlation coefficient of calibration curve shows a high degree of closeness of predicted value to that of reference values

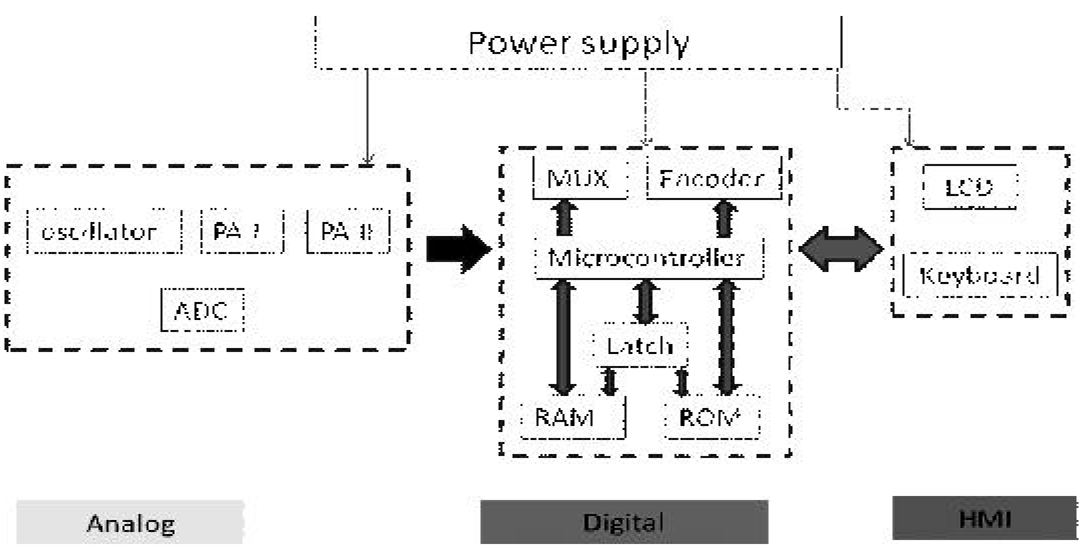

Fig. 2—Microcontroller based block diagram

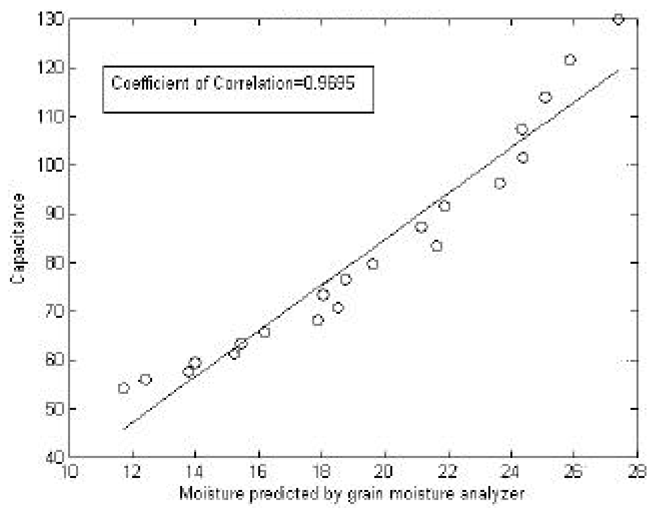

Fig. 3—Plot showing capacitance *vs* predicted moisture by grain analyser

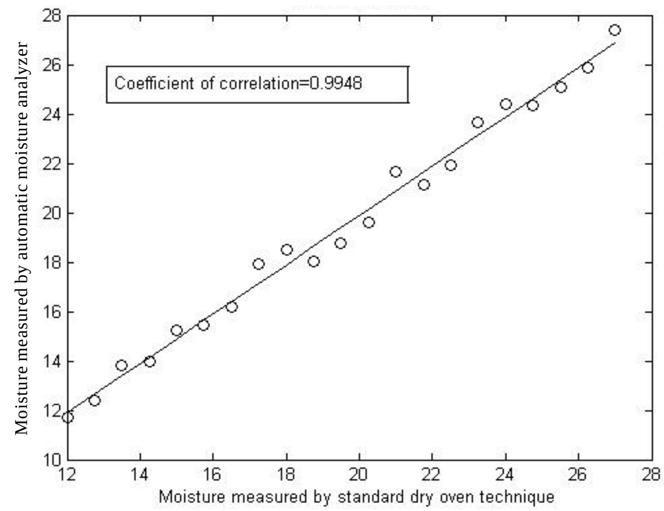

Fig. 4—Plot showing predicted moisture by grain analyser in comparison with dry oven method

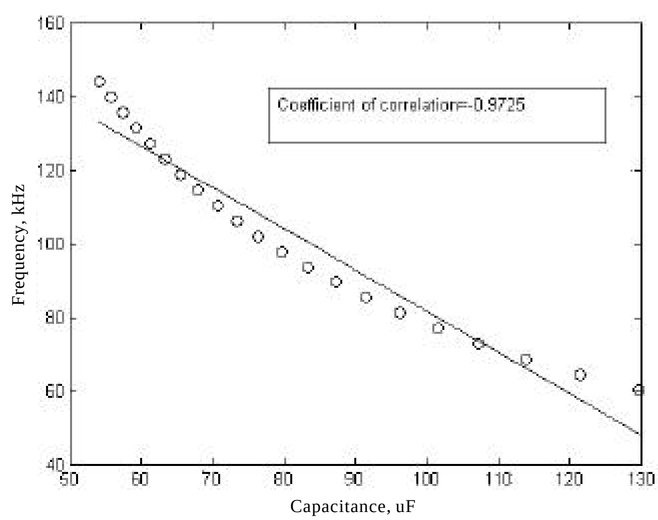

Fig. 5—Plot showing frequency *vs* capacitance

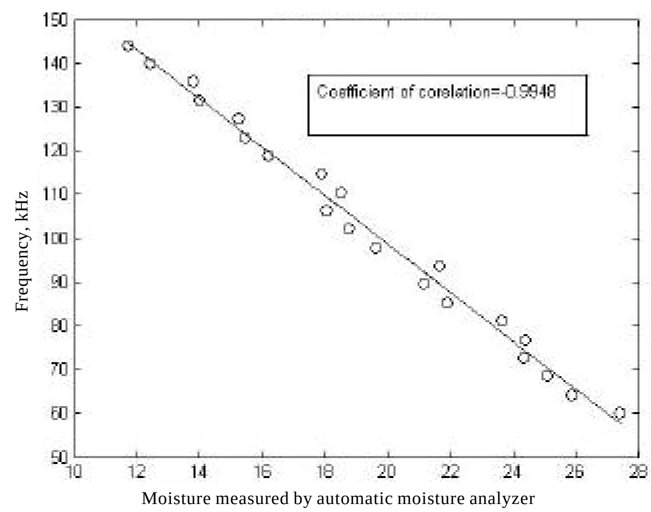

Fig. 6—Plot showing standard moisture *vs* frequency

[dry oven technique (DOT)] on wet basis (Fig. 4). A high degree of correlation has been found between data obtained from DGMA and DOT. Frequency response shows behavior of oscillator used for capacitance developed across dielectric cell by grains poured in it. Designed oscillator circuit produces inverse relation between capacitance generated by grain sample and frequency response produced at the output (Fig. 5). Plot (Fig. 6) showing output response measured as a frequency (kHz) corresponding to moisture values represents near to most desired performance requirement out of any sensor electronics, producing moisture measurements within 1% accuracy when compared with DOT (wet basis). As can be seen in capacitance vs moisture plot, it varies linearly towards positive slope of line showing close direct correlation amongst them.

Conclusions

Non-linearity of measurement data from moisture analyzer for Indian wheat has been corrected using curve fitting techniques to develop an analyser specific prediction model to predict accurately moisture determination in desired range (7-35%). Evaluated performance found to be closely correlated with that of standard DOT in an acceptable and useful range (7-35% moisture contents). Such an electrical measurement helps reduce labour intensive and time consuming direct measurement procedures into a less time consuming indirect meter development in closed range and hence can be worth for commercial use.

References

1 Nelson S O, Use of electrical properties of grain-moisture measurement, *J Microwave Power*, **12** (1977) 67-72.

2 Nelson S O, Electrical properties of agricultural products- A critical review, *Trans ASAE,* **16** (1973) 384-400.

3 Nelson S O, Sensing moisture content in grain, *IEEE Instru Measurmt Mag,* (March 2000) 1720.

4 Nelson S O & Trabelsi S, Principle for microwave moisture and density measurement in grain and seed, *J Microwave Power Electromagnetic Energy*, **39** (2004) 107-117.

5 Rai A K, Khare P K, & Mor P, Microprocessor based measurement system for grain moisture, in *Proc Int Conf Info Comm Tech Elec Sci* (Dr M G R University, Chennai) 2007, 850-856.

6 Ki-Bok K, Jong-Heon K, Seung Seok L, & Sang Ha N, Measurement of grain moisture content using microwave attenuation at 10.5 GHz and moisture density, *IEEE Trans Instru Measurmt*, **51** (2002) 72-77.

7 Rollwitz W L, Nuclear magnetic resonance as a technique for measuring moisture in liquids and solids, *Humidity Moisture* **4** (1965) 149.

8 Zeleny L, Moisture measurement in grain industry, *Cereal Sci Today*, **5** (1960) 130-136.

9 Nelson S O, A mathematical model for estimating the dielectric constant of hard red winter wheat, *Trans ASAE*, **28** (1985) 234-238.

10 Nelson S O, Moisture frequency and density dependence of the dielectric constant of shelled, yellow-dent field corn, *Trans ASAE*, **27** (1984) 1573-1578.

11 Nelson S O, A model for estimating the dielectric constant of soybeans, *Trans ASAE,* **28** (1985) 2047-2050.

12 Nelson S O, A mathematical model for estimating the dielectric constant of hard red winter wheat, *Trans ASAE,* **28** (1985) 234-238.

13 Nelson S O, Mathematical model for the dielectric constant of spring barley and oats, *Trans ASAE,* **29** (1986) 610-615.

14 Nelson S O, Models for estimating the dielectric constant of winter barley, *Int Agrophysics,* **2** (1986) 189-200.

15 Nelson S O, Models for the dielectric constant of cereal grains and soybeans, *J Microwave Power,* **22** (1987) 35-39.

16 Kraszewki A & Nelson S O, Composite model of the complex permittivity of cereal grain. *J Agric Eng Res*, **43** (1989) 211-219.