UNIVERSITI PUTRA MALAYSIA

ELECTROMAGNETIC CHARACTERISTIC OF OPEN ENDED COAXIAL AND OPTICAL FIBRE TECHNIQUES FOR MOISTURE CONTENT MEASUREMENT IN MAIZE

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ELECTROMAGNETIC CHARACTERISTIC OF OPEN ENDED COAXIAL AND OPTICAL FIBRE TECHNIQUES FOR MOISTURE CONTENT MEASUREMENT IN MAIZE

By

MOHAMAD ASHRY BIN JUSOH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

January 2012

Specially dedicated to:

My Lovely Mother,

Brothers,

Sisters

and

In memorial: Father

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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January 2012

Chairman : Zulkifly Abbas, PhD

Faculty : Science

This thesis describes an electromagnetic characteristic of open ended coaxial and optical fibre techniques for moisture content measurement in maize kernel based on reflectivity measurements. Both analytical and numerical methods were employed to calculate the reflectivity of the sensors. The former utilized the admittance model whilst the latter was implemented using Finite Element Method (FEM). The admittance model is an analytical equation based on integral equation for electric field at aperture. Computation of reflectivity using FEM is based on the solutions of a set of partial differential electric field equations. The FEM modelling was implemented using COMSOL Multiphysics version 3.5 software. Permittivity values required as inputs to admittance and FEM that were obtained from dielectric mixture model.

The measurement setups for open ended coaxial technique consist of Agilent Professional Network Analyzer (PNA-L N5230A) in microwave frequency range between 1 GHz and 5 GHz. The calibration was performed using a full one-port calibration technique. The optical fibre technique reflectivity measurement was realized using Ocean Optic Spectrometer (USB4000) with an operating wavelength between 230 nm and 800 nm.

In this work, the open ended coaxial technique involves both magnitude and phase whilst the optical fibre only provides the reflectivity value (magnitude only) The FEM results showed better agreement with measured data than the admittance model for both sensors. The effect of mesh was studied thoroughly and was found that the maximum relative errors for FEM with 4454 number of elements were 0.0093 and 0.0861 for magnitude and phase respectively.

Calibration equations have been established to determine moisture content in maize based on reflectivity measurements using both open ended and optical fibre sensors. The actual moisture content was found from standard oven drying method. The mean percentage errors of the calibration equations were found to be less than 4.32 % and 4.02 % for magnitude and phase of reflection coefficient respectively. While for optical fibre sensor, it was found that the mean percentage error are 12.23 % and 9.16 % for 300 nm and 800 nm respectively.

The empirical models have been developed to predict permittivity of maize based on measured reflection coefficient of sensors. The mean percentage errors were found to be less than 10 % when compared to commercial values. Enhanced accuracy of

prediction of permittivity was obtained by introducing an objective function to determine unknown parameters of the mixture model.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

CIRI ELEKTROMAGNET PADA TEKNIK SEPAKSI HUJUNG TERBUKA DAN SERABUT OPTIK UNTUK PENGUKURAN KANDUNGAN KELENGASAN DALAM JAGUNG

Oleh

MOHAMAD ASHRY BIN JUSOH

Januari 2012

Pengerusi : Zulkifly Abbas, PhD

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Tesis ini memperihalkan ciri elektromagnet pada teknik sepaksi hujung terbuka dan serabut optik untuk pengukuran kandungan kelengasan dalam jagung berasaskan pengukuran pantulan. Kedua-dua kaedah analitis dan berangka telah digunakan untuk mengira pantulan oleh penderia. Yang pertama menggunakan model masukan sementara kedua dilaksanakan dengan menggunakan Kaedah Elemen Hingga (FEM). Model masukan adalah persamaan analitis yang berdasarkan persamaan kamiran untuk medan elektrik di bukaan. Perhitungan pantulan menggunakan FEM didasarkan pada penyelesaian dari satu set persamaan pembezaan separa medan elektrik. Pemodelan FEM dilaksanakan dengan perisian COMSOL Multiphysics versi 3.5. Nilai ketelusan diperlukan sebagai input untuk masukan dan FEM dan diperolehi daripada model campuran dielektrik.

Persediaan pengukuran untuk teknik sepaksi hujung terbuka terdiri daripada Agilent Profesional Network Analyzer (PNA-L N5230A) dalam julat frekuensi gelombang mikro antara 1 GHz dan 5 GHz. Penentukuran dilakukan dengan menggunakan teknik tentukuran penuh satu-pangkal. Teknik pengukuran pantulan gentian optik diwujudkan dengan menggunakan Spektrometer Ocean Optic (USB4000) dengan panjang gelombang operasi antara 230 nm dan 800 nm.

Dalam kajian ini, teknik sepaksi hujung terbuka melibatkan kedua-dua magnitud dan fasa sedangkan gentian optik hanya menyediakan nilai pantulan (magnitud saja). Keputusan FEM dengan data yang diukur menunjukkan persetujuan yang lebih baik dari model masukan untuk kedua-dua penderia. Kesan jejaring dipelajari secara menyeluruh dan didapati bahawa ralat relatif maksimum untuk FEM dengan 4454 jumlah elemen adalah masing-masing 0.0093 dan 0.0861 untuk magnitude dan fasa.

Persamaan tentukuran telah dibentuk untuk menentukan kelengasan dalam jagung berdasarkan pengukuran pantulan menggunakan kedua-dua penderia hujung terbuka dan gentian optik. Kelengasan yang sebenarnya diperolehi daripada kaedah piawai pengeringan ketuhar. Min peratusan ralat untuk persamaan tentukuran didapati masing-masing kurang dari 4.32 % dan 4.02 % untuk magnitud dan fasa pekali pantulan. Sedangkan untuk penderia gentian optik, didapati bahawa min peratusan ralat adalah masing-masing 12.23 % dan 9.16 % untuk 300 nm dan 800 nm.

Model empirik telah dibangunkan untuk meramalkan ketelusan jagung yang diukur berdasarkan pekali pantulan oleh penderia. Min peratusan ralat didapati kurang dari 10% bila dibandingkan dengan nilai komersial. Peningkatan ketepatan ramalan

ketelusan diperolehi dengan memperkenalkan fungsi objektif untuk menentukan parameter yang tidak diketahui dari model campuran.

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I certify that a Thesis Examination Committee has met on 9th January 2012 to conduct the final examination of Mohamad Ashry Bin Jusoh on his thesis entitled "**Electromagnetic Characteristic of Open Ended Coaxial and Optical Fibre Techniques for Moisture Content Measurement in Maize**" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P. U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of Doctor of Philosophy.

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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MOHAMAD ASHRY BIN JUSOH

Date: 9th January 2012

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