Measurement of Dry Rubber Content in Latex Using Microwave Technique

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Abstract: *This paper deals with an experimental study on the dielectric properties of natural rubber as a function of dry rubber content. The cost of rubber is directly dependant on the dry rubber content and therefore the study gains its importance. It shows that the dielectric properties of Hevea latex are mainly due to the orientation of loosely bound water molecules .The experiment was done at room temperature using a dielectric liquid cell used to hold the sample of natural rubber under study. The study comes to the inference that there is an inversely proportional relationship between the dry rubber content and its dielectric constant. i.e as the moisture content increases, the dielectric constant also increases.*
Keywords,dielectric constant ,latex, dry rubber

1.Introduction:

In this paper, the determination of dry rubber content in the natural latex obtained from *Hevea Brasiliensis* is carried out. A brief introduction of latex contents is given below. Latex is the protective fluid contained in the tissue beneath the rubber tree Hevea Brasiliensis.Natural Rubber Latex (NRL) is a cloudy, white liquid, similar in appearance to cow's milk. Cutting a thin strip of bark from the tree and allowing the latex to exude into a collecting vessel over a period of hours collect it.

Table 1. Composition of latex

Constituents	% Composition
Rubber particles (cis-1, poly isoprene)	30.0-40.0
Protein	2.0-3.0
Water	55.0-65.0
Steril glycosides	0.1-0.5
Resins	1.5-3.5
Ash	0.5-1.0
Sugars	1.0-2.0

Natural latex not only contains the polymer rubber but many other (NRS) Non Rubber Solids, most of which are proteins as tabulated. Most of the proteins seen in natural rubber are found to be allergy causing to the human body if held in contact for a long period. Therefore industries demand for rubber with a high dry rubber content (DRC) and with the least percentage of NRS. Before moving on to the electronic method of dry rubber determination let us have a glance on the conventional method of DRC determination.

A small quantity of the natural latex is taken as sample to determine the DRC. Ammonia gas is added to the sample to prevent the latex from being solidified. It is then weighed to find the weight of latex along with the container. Acetic or formic acid is added to the weighed sample. This will separate the rubber solids from the serum, which includes water, and nonrubber solids. The rubber solid is then pressed and dried using an oven until the water content gets evaporated. This process of drying may extent to several hours or days. The dried rubber is then weighed again and the percentage of DRC is calculated.

The presently used conventional method suffers from the demerit of consuming long time as well as not being able to completely remove the allergy causing proteins from the natural rubber. There is another conventional method in which the natural rubber latex is concentrated by evaporation. But the drawback is that the NRS are not completely removed. Therefore enzymes are added in order to break down the proteins and then residues are removed. Still the drawback follows, as the additives are capable of causing skin reactions. Thus the electronic method of dry rubber content determination using microwaves gains significance in the present scenario where rubber has huge economical importance and industrial demand.

Hevea latex being a biological product of aqueous serum, the prediction of the dielectric properties is very complicated. Natural rubber comes under the low-loss dielectrics that are found to be electrical insulators. Dielectric properties of these low-loss dielectrics show little variation with frequency over the microwave range. This is because the fresh latex consists of 55-80% of water, 15- 45% rubber hydrocarbon and about 2-4% of non-rubber constituents. Moreover, the changes in season, soil, tapping methods, weather etc; exhibits wide variation in the composition of the natural latex.[5].

The experiment was conducted in two methods.The first method involves in finding a relation between the dry rubber content of various samples and its respective dielectric constants, whereas the second method deals with varying the moisture (water) content of a sample and finds the varying dielectric constants. The dielectric properties considered are the relative complex permitivity,ε=ε'-jε''.The real part is referred to as the dielectric constant and the imaginary part is the dielectric loss factor.

2. Subjects and Methods:

Water, a major component of Hevea latex is a polar molecule. As a result, when placed in an electric field, positive and negative charges move in opposite directions and the water molecules will tend to rotate so that their dipoles align with the field. The ability to polarize, namely the orientation of dipoles determines the dielectric constant of the medium, ε'. The dielectric loss, ε''reflects the ability to dissipate the electromagnetic energy, that is to convert it into heat. Dielectric properties of liquid not only depend upon the water content but also are also strongly dependent upon the geometrical shape of the water particles. It is usually assumed that the shape of the water molecule is ellipsoidal.

In dielectric materials, most of the charge carriers are bound and cannot participate in electrical conduction. However, if an external electric field is applied to the material, these bound charges may be displaced. This displacement of charge creates a dipole field that opposes the applied field and the material is polarized.

In a linear isotropic medium, the volume density polarization is directly related to the applied electric field intensity. Electric field intensity D is related to the polarization density and the electric field intensity as follows.

$$D = \varepsilon_0 E + P = \varepsilon E = \varepsilon_0 \varepsilon_r E$$

Where ε is called permitivity of the material. It is also known as the dielectric constant of that material. A time varying electric field induces two different kinds of currents in a material medium. Conduction current is produced by a net flow of free charges, and the bound charges generate a displacement current. Total current density is the sum of conduction and displacement current. Hence

$$J_T = \sigma E + j\omega\varepsilon E \quad = j\,\omega\,(\varepsilon - j\sigma/\omega)E = j\omega\varepsilon^* E$$

where $\varepsilon^* = (\varepsilon - j\sigma/\omega)$ is known as complex dielectric constant

$$\varepsilon^* / \varepsilon o = (\varepsilon/\varepsilon o - j\sigma/\omega\,\varepsilon o) \quad = \quad \varepsilon' \; - \varepsilon''$$
$$= \varepsilon' \, (1 + \tan\delta)$$

tan δ ,which represents the ratio of power lost in the in the dielectric to the energy stored per cycle in the dielectric is known as loss tangent.

There are many ways in which dielectric measurements may be made [7].Out of these methods we used 'two point method'. This type of measurement is perhaps the best known and most widely used. The method to measure dielectric constant is briefly explained below.

Consider an empty short-circuited wave guide with a probe located at voltage minimum D_R, the same wave guide now containing a sample of length l_E with a probe located at a new voltage minimum D.The impedance equation is

$$Z_o \tan\beta l = -Z_E \tan \beta_E l_E$$

where Z_o & Z_E are respectively the characteristic impedance of empty and dielectric-filled wave guides and β and β_E are respective propagation constants.[7]

Now, consider the expression

$$\tan\beta(D_R - D + l_E) = \tan\beta(l_R + l_e)\_(l + l_E) + l_e)$$

$$= \tan\beta\{(l_R + l_e)\_l\}$$

Expanding the tangent sum angle and making use of $Z_O \tan\beta(l_R + l_e) = 0$,

we obtain

$$Z_O \tan\beta(D_R - D + l_E) = Z_E \tan \beta_E l_E$$
$$\tan\beta(D_R - D + l_E)) / \beta l_E = (\tan \beta_E l_E) / \beta_E l_E$$
$$\varepsilon_r = [(a/\Pi)^2 . (x/l_E) + 1]/(2a/\lambda_g^{\cdot)}$$
$$\text{where } x = \beta_E l_E$$

This equation suggests a method for measuring dielectric constant.

Two-point method is used for measuring dielectric constant of both low-loss solid dielectrics and liquid dielectrics or solutions. Here we employ the method in determining the dielectric constant of low-loss dielectric natural rubber latex. The equipments required include the microwave source, source of power supply, frequency meter, directional coupler, attenuator, tuned detector, slotted wave guide section, dielectric cell and the indicating meter which are shown in the experimental arrangement(Fig.1)

The input power was kept fixed and the distances of first V_{min} and second V_{min} are noted. Also the values of V_{min} and V_{max} were noted from the indicating meter. The above steps were repeated after connecting the empty dielectric liquid cell. The liquid cell was then filled with 20ml of a sample .The values of distances of first and second V_{min} and values of V_{min} and V_{max} were noted down. The procedure was repeated for all the samples whose dielectric constant was to be found.

In the second method sample was taken and diluted with water (moisture content) thus preparing many samples,each with the same volume. The moisture content of samples was varied from 10-40%. The diluted samples were prepared by adding the latex concentrate with water. The steps in method 1,i.e;observation of distances of first and second V_{min},values of V_{min} , V_{max} was then carried out. The same procedure was repeated with all other samples.

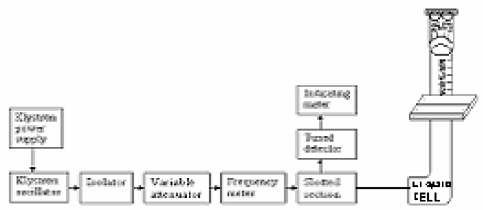

Fig.1.Experimental arrangement

The equipments used in the experiment were assembled as shown in the Fig 1.The microwave power source was energized and suitable power level obtained in the indicating meter. With no sample (liquid),in the cell, the positions of standing wave minima starting from any arbitrary plane were measured and recorded. Guide-wavelength, the distance between alternate minima,(λ_g / 2) was computed. Using frequency meter the frequency of the excited wave was determined and free space wavelength was computed. It can also be computed knowing λ_g from

$$(l / \lambda_o)^2 = (l / \lambda_g)^2 + (l / \lambda_c)^2$$

The cell was then detached carefully and filled with a known volume (20ml) of the liquid sample. The height of the liquid in the cell (volume/area=V/ab) was then calculated. The positions of voltage minimum were recorded and V_{max} and V_{min} values were noted down. Finally the wave-guide dimensions were also measured. The observed and calculated readings are shown in table (1&2)

Table 1.

S.No	DryRubber Content(%)	Dielectric constant
1.	44.8917	0.5477
2.	42.8494	0.5479
3.	38.2277	0.5486
4.	35.5905	0.5488
5.	34.0365	0.5492
6.	33.6387	0.5495
7.	31.8902	0.5497
8.	28.9111	0.5501
9.	27.8728	0.5503
10	23.8499	0.5506

Table 2.

Sampl No	DRC %	Moistu Conten (%))	D_R(cm)	Dielectric constant
1.	23.8499	10	15.04	0.5481
		20	14.99	0.5490
		30	14.94	0.5499
		35	14.86	0.5512
		40	14.85	0.5514
2.	33.8499	10	15.05	0.5479
		20	15.00	0.5488
		30	14.96	0.5495
		35	14.90	0.5505
		40	14.86	0.5511
3.	38.22	10	15.06	0.5477
		20	15.02	0.5484
		30	15.00	0.5490
		35	14.99	0.5404
		40	14.96	0.5509
4.	44.89	10	15.08	0.5473
		20	15.04	0.5483
		30	15.00	0.5492
		35	14.98	0.5402
		40	14.96	0.5512

3.Result:

The inferences of the experiments done in two different methods are summarized in the figures(2-5) which shows the moisture dependence of the dielectric properties of the Hevea rubber latex at room temperature. The water molecules in the Hevea latex are loosely bound and easily aligned to the electric field. The dielectric properties of latex are mainly due to the orientations of water molecule and the shape of the molecule is spheroid. Non-rubber constituents do not contribute much to the dielectric properties of Hevea latex.

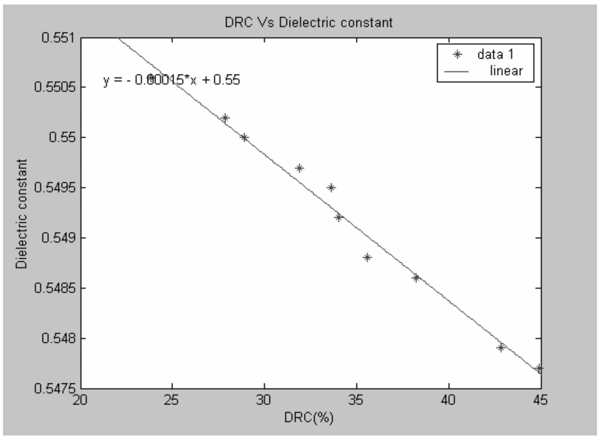

Fig.2

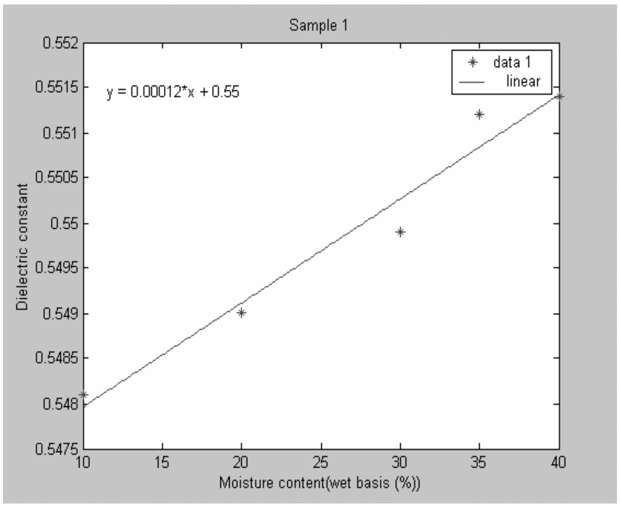

Fig.3

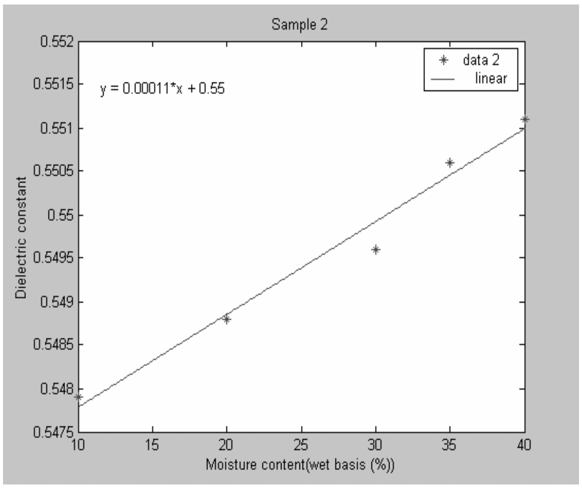

Fig.4

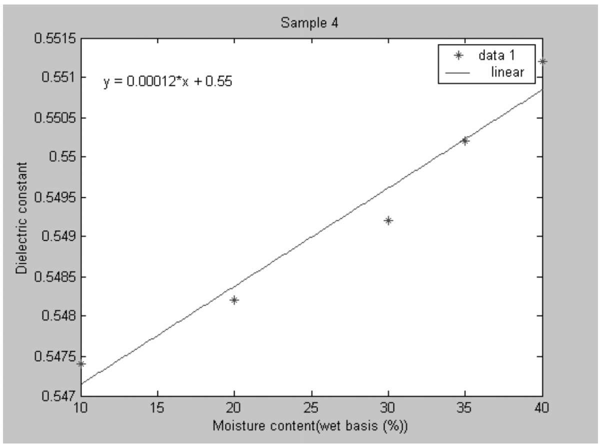

Fig.5

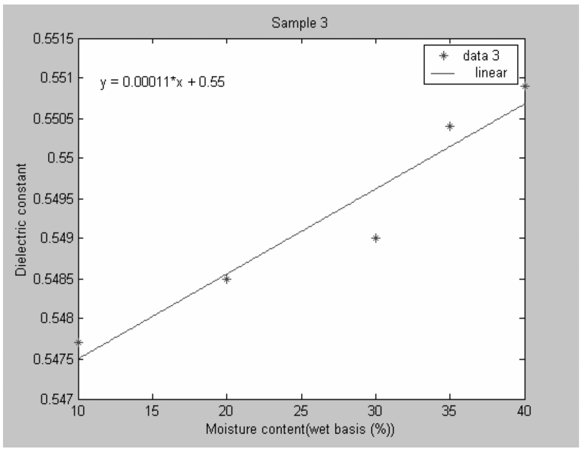

Fig.6

Conclusion:

The paper is concluded showing a relation between moisture content and dielectric constant. The larger the moisture content, the higher the values of ε'.Although Hevea latex is a very complex material, a good relationship between the dielectric properties and moisture content is obtained.

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