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FWHM dimensional analysis from scattered light intensity profile for dry rubber content determination in natural rubber

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A B S T R A C T

Dry Rubber Content (DRC) describes a rubber particle percentage in natural rubber latex. In this paper, the relation between forward light scattering profiles of natural latex and rubber contents is reported for dry rubber content latex. The profile, characterized by Full Width at Half Maximum (FWHM), is increasing linearly with respect to rubber content. The measurement was performed immediately after latex being tapped with necessary addition of ammonia. This addition was meant to prevent latex coagulation. There is a high linear correlation between DRC and FWHM of both domains: one and two dimension. This is indicated by correlation factor r^2 which are higher than 0.9 for both of domains and sufficient in DRC determination.

1. INTRODUCTION

Natural Rubber Latex (NRL) is a white suspension tapped from *Hevea* tree. This suspension is mainly composed of rubber particle and water. Other substances, such as proteins, acid and inorganic material, are also contained in it at a small portion(Ho, 2014; Berthelot et al., 2014). The economic value of NRL is determined by the quantity of rubber expressed in term of dry rubber content (DRC). The DRC is defined as a percentage of solid dry rubber content obtained from dehydrated 100-gram of NRL (Zhao et al., 2010).

The standard method of measuring DRC is recommended by The International Organization for Standardization (ISO)(Standardization, 2005). In this method, a direct measurement of DRC is performed by weighing solid substance produced from coagulating and drying 100 grams of fresh latex. This method is an exhausting process which takes approximately 12 hours to ensure residual water content removal. In term of practicality, this method is difficult to be applied in daily NRL price estimation.

On the other hand, a quick estimation of DRC can be done indirectly using the measurement of latex physical properties. A level of DRC then can be inferred by making a correlation between DRC and those properties. Such physical properties include dielectric permittivity (Julrat et al., 2012), density (Tillekeratne et al., 1988), light scattering and reflectivity (Zhao et al., 2010; George et al., 2013), microwave reflection, transmission and resonant frequency

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(Aiyarak and Sunheem, 2015; Sunheem and Aiyarak, 2016)(Fizik et al., 1982).

Light scattering concept has been widely applied in a turbid medium (Moitzi et al., 2009) to infer suspension particles properties. Furthermore, the relation between DRC and scattering light profile of turbid medium has been studied experimentally by Nibu (George et al., 2013). In that study, a linear relation is indicated between DRC and full width at half maximum (FWHM) intensity of horizontal forward scattering profile. This paper develop Nibu's study which extends the calculation of FWHM on two-dimensional domain: an area of forward scattering angle, also compare linear correlation both one and two-dimensional domain.

2. METHODS

Apparatus & Reagent

The experimental setup, used to capture traversing light, is shown in

Figure .

A red commercial laser diode was used as a light source with 5mW maximum power. The laser intensity can be adjusted to the desired level by applying appropriate voltage. A latex container made of acrylic was installed close to laser diode. The acrylic thickness was 1.5 mm. The dimension of the container is 10 mm x 100 mm x 60 mm. The container wall acts as a screen where scattered light was projected at. To capture this projection, Xiaomi Yi acts as digital camera was installed and placed at 10 cm from the container. All of these parts were put inside the well-covered box (see figure 2) which ensured that no ambient light was recorded. For standardization, the rubber content of those six samples was measured using standard method (Standardization, 2005).

Procedure

Light scattering by particles is affected by several factors, such as particle concentration, structure, dimension, light wave number, and sample thickness (Mischenko, 2004). By making a variation of particle concentration and keeping the other factors constant, the relation between concentration and scattering intensity can be experimentally established.

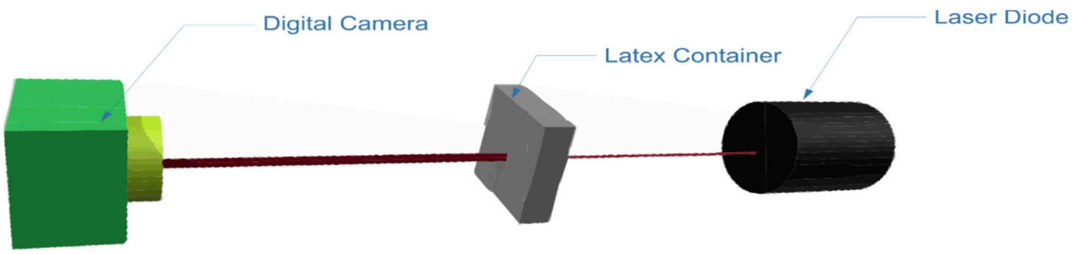


Figure 1. Experimental Setup

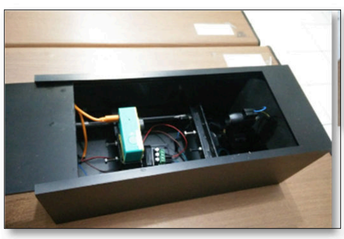


Figure 2. Box for Instrument Setup

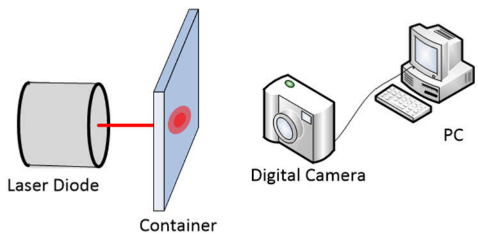


Figure 3. Experiment setup for measuring Dry Rubber Content (DRC) of latex.

The latex used in this experiment was a fresh latex, analyzed within one hour after tapped. To maintain its liquid form, 20% of ammonia was added. Variation of sample concentration was made by diluting latex with known volumes of water. In this experiment, six sample was prepared by diluting six 100 mL cups of latex with 10, 20, 30, 40, 50 and 60 ml cups of water volume respectively. The scattered light profile of those six samples was captured and stored on a personal computer.

The first step of this standard analysis was coagulating DRC in fresh NRL by adding acetic acid and followed by heat it on the steam bath for 30 minutes. The next step was drying the coagulum in the oven at 75 C° until drying mass was stable. It took approximately 12 hours to remove any left-over water content.

3. RESULT AND DISCUSSION

The recorded images, as can be seen in figure 3(a), were in RGB format which read by MATLAB as three layers of matrix colors (Red, Green and Blue) ranging from 0 to 255. As light source was a red laser, then green and blue layers were filtered out and leaving only a red layer. Next, this red layer is smoothed using a Gaussian filtering method. The 3-D representation of this smoothed light scattering is shown in Figure 4(b), where the top figure is a surface plot of scattered light while the bottom is contour plot.

The light scattering profile can be characterized by calculating the FWHM of its intensity distribution. FWHM is calculated as the total number of pixels at which intensity is higher than half of the maximum intensity. The dimensionsat which pixels is evaluated can be either a surface (two-dimensional FWHM) or a line (one-dimensional FWHM). Two-dimensional FWHM calculation can be demonstrated by projecting scattered light onto contour plot and counting pixels at which intensity is higher than half maximum intensity. Figure 4(a) is contour plot of the same scattered light profile as seen in Figure . Based on the figure, the maximum intensity is 126. Hence, half maximum is 63 and identified as green color. FWHM of this particular scattered light is approximately a circular area within the green line.

On the other hand, one dimensional FWHM can be calculated as a number of pixels at which intensity is half of the maximum intensity at particular line position. Scattered distribution at line 560 is shown in figure 4(b). The corresponding FWHM is the width between green points as indicated in the figure.

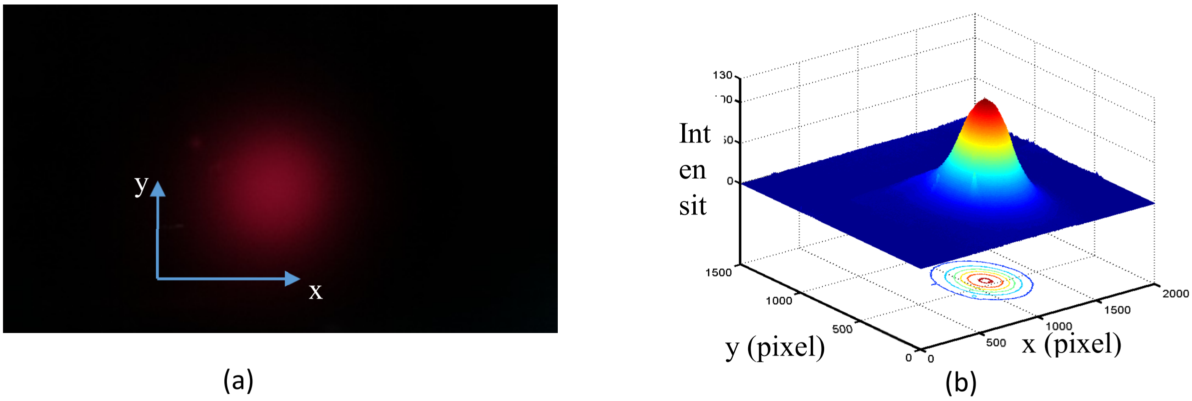
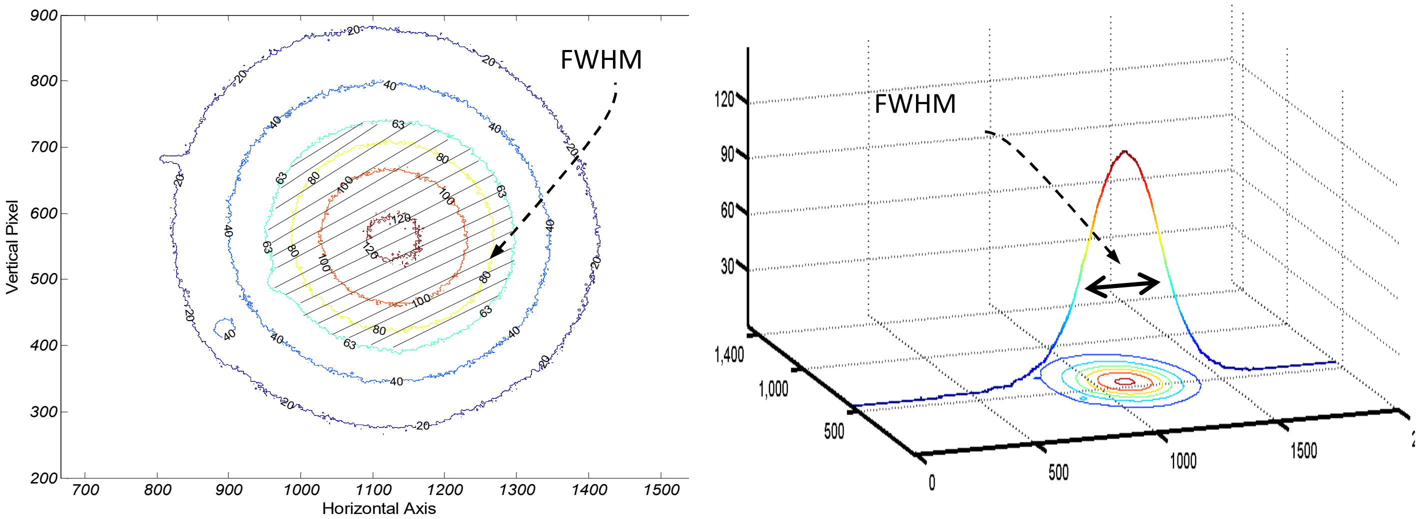


Figure 4.(a) Typical recorded image of scattered light from latex. (b) Three-dimension representation of scattered light image.



(a) (b)

Figure 5. (a) Contour plot of scattered light. (b) One dimension of scattered light is plotted overlying scattered contour plot.

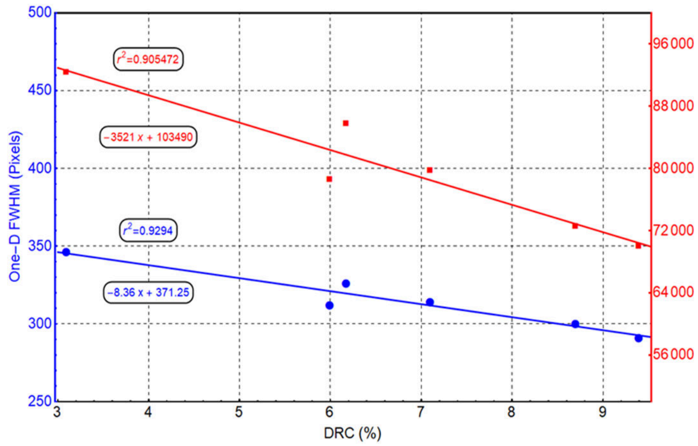


Figure 6. FWHM values as the function of DRC from two domain calculations: Blue (one dimension) and Red (two dimensions)

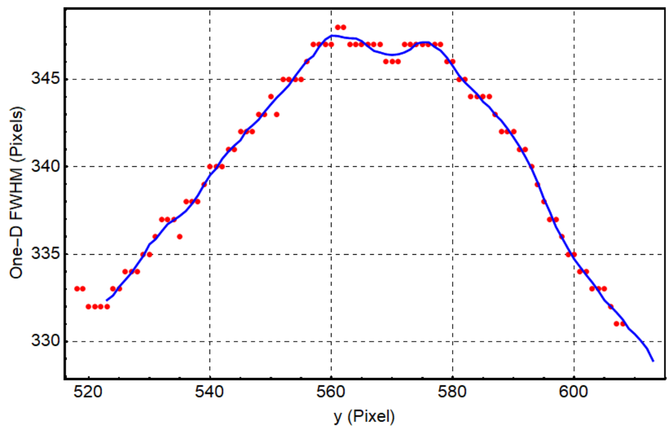


Figure 7. Various one-dimensional FWHM values as a function of y position (pixel).

Two-dimensional FWHM is calculated as an area of nearly-circular-shape of green line at which the intensity is 63 (figure5(a)). This intensity is half of the maximum intensity which is 126. One dimensional FWHM calculation is width where pixels are higher than half of the maximum. In this figure, a half maximum is indicated by green color those two plots (figure5(b)).

Six images of six different samples have been recorded. FWHM of those images were also calculated. The relation between FWHM and rubber content is shown in figure 6. The Figure is color coded based on FWHM calculation method. Blue color indicates pixels number of one-dimensional FWHM horizontal line $y = 560$ while red color represents those of two-dimensional FWHM. A horizontal line $y = 560$ was chosen due to the fact that at this position, FWHM is at maximum with respect to other horizontal lines (figure 7).

As can be seen from figure 6, there is a high linear correlation between DRC and FWHM of both domains: one and two dimensions. This is indicated by correlation factor r^2 which are higher than 0.9 for both of domains. Two points at about 6% of DRC concentration show irregularity while the others four points only slightly differ from the linear plot. For this result as (Van Loco et al., 2002) suggested r values > 0,997, some explorations should be made, like enriching the data base and latex container modification.

Red points show the measured data and the continuous blue line are smoothed data by a savoy-golay algorithm (Persson and Strang, 2003).

4. CONCLUSION

In conclusion, a linear relation between scattering light profile and rubber content has been demonstrated for low rubber content latex in both one and two- dimensional analysis. Our calculation indicates this analysis has correlation factor r^2 which are higher than 0.9 for both one and two-dimensional analysis and other explorations still possible to be accomplished.

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