Predicting the Performance of Washable Paints Produced from Jatropha Seed Oil Using Power Law Model

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***Abstract*:- Each of the processes and stages in paint production and application are represented by a particular shear rate. As a result, paints behave differently under these shear rates, and as single rotational viscometer may not be able to determine these behaviours at certain shear rates. To predict the behaviour of paints outside the measured shear rates, power law model which is a simple mathematical tool for determining the rheological behaviour of fluid becomes important. This work studied the use of power law model in predicting the behaviour of washable paint: a type of waterborne paint, produced from jatropha seed oil. Waterborne coatings are non toxic, but they do not have excellent rheological properties compared to those of solvent based paint. Therefore, it is necessary to predict how this paint will behave at different stages of processing: pumping, canning, mixing and storage. This will help in reformulation of the sample to satisfy specific need if there is need. The rheological properties were determined by measuring the average viscosity of the sample using a rotational viscometer at the shear rates of 06 rpm, 12 rpm, 30 rpm and 60 rpm. The average viscosity readings at the shear rates are 1061 mPa.s, 533.5 mPa.s, 214 mPa.s and 107.1 mPa.s respectively. These readings were converted to logarithmic values; 3.0257, 2.7197, 2.3181 and 2.0298 respectively. These values were then, used to determine the power law parameters n (0.6602) and k (2344.23mPa.s), and correlation coefficient of 0.9960 through regression analysis. The results describe the applicability of the power law model to predict the viscosity and the behaviour of the sample at different shear rate, and also quantify the shear thinning behavior of the product.**

***Keywords:* Rheological properties, viscosity and power law model**

I. INTRODUCTION

Waterborne coatings are gradually taking over the coating industry as most countries have prohibited the use of coatings with high volatile organic content (VOC). Most of these VOC which are toxic to human and the environment are from solvent-based coating (Njuku et al, 2014). Waterborne coatings include paints in which water is used as the solvent. Such paints are; emulsion, washable paints among others. These coatings usually display inferior rheological properties if not properly formulated (TA, 2015). These inferior rheological properties can be determined and corrected before the products are packaged and distributed.

Rheological characteristics of a material not only influence its visual and textural perception, but also have effect on its processing capabilities (Malvern, 2015). Paints as shear-thinning materials are susceptible to applied stress, it is therefore important to measure their shear thinning behavior as this will be an indirect measurement of product quality and consistency. A direct assessment of processing ability of products can also be obtained. For example, the viscosity of a fluid will determine the power for the pumping system, a high viscosity liquid requires more power to pump than a low viscosity one. Knowing its rheological behavior, therefore, is useful when designing pumping and piping systems (Ametek, 2005). They are also a way to predict and control a host of product properties, end use performance and material behavior (Ametek, 2005).

Most time, two products that give similar single-point viscosity readings with same spindle at same rpm will exhibit different flow properties in the real world. Results of average viscosity test are very important in rheology world, because the appearance of the sample may contradict the viscometer reading. Once the viscometer reading is taken, then those differences will be quantified with a simple rheological model. Power Law (or Ostwald) Model can be used to fit a typical viscosity versus shear rate or stress versus shear rate curve within the range (Tim, 2016). Every process and stage in paint manufacturing is depicted by a particular shear rate. As a result, paints behave differently under these shear rates, and as single rotational viscometer may not determine these behaviours at certain shear rates. To predict the behaviour of paints at other shear rates within the measured shear rate of the viscometer, power law model is used. Power law model can be fitted to predict the characteristics of fluid at different shear rates. Once there is a correlation between rheological data and product behavior, the procedure can then be reversed and rheological data may be used to predict performance and behavior (Ametek, 2005).

This work, studied the rheological characteristics of washable paint produced from jatropha seed oil using power law (Ostwald de Waele) model.

II. MATERIALS AND METHODS

Rheological characterization of paint produced from jatropha seed oil was carried out with a rotational viscometer at the shear rate of 06rpm and 60rpm. The viscometer measured the average viscosity of the paints at different shear rates, and the result is recorded in table 1. The result was fitted into the linear equation (2) of power law model of equation (1) given below.

$$\eta = k\gamma^{n-1} \qquad 1$$

The model was converted to a linear model by taking the log of both sides. The regression equation of (1) is written as equation (2).

$$\log \eta = n - 1 \log \gamma + logk \qquad 2$$

Plots of Logη against logγ will give a straight line of slope antilog k and intercept n-1. Antilog of k gives the value of consistency (k) and n gives power law **or flow** index. **n** is a measure of non-Newtonianness. For a Newtonian fluid, n = 1; for a shear-thinning fluid it is between 0 and 1 and for a shear thickening fluid it is greater than1. With the known values of k and n, the viscosity can be estimated at any shear rate.

III. RESULTS AND DISCUSSIONS

Table 1 shows the average viscosity reading from a rotational viscometer measured at shear rates of 06 rpm, 12 rpm, 30 rpm and 60 rpm respectively. The values in table 1 were converted to log readings, and are recorded in table 2. This was fitted into linear graph of figure 1.

Table 1: Variation of Viscosity With Shear Rate

γ(rpm)	η (mPa.s)
06	1061
12	533.5
30	214
60	107.1

γ(rpm) stands for share rate and η stands for viscosity (mPa.s)

Table 2: Log of Viscosity (Log η) and Log of Shear Rate (Log γ)

Log γ	Log η
0.7782	3.0257
1.07918	2.7197
1.47712	2.3181
1.77815	2.0298

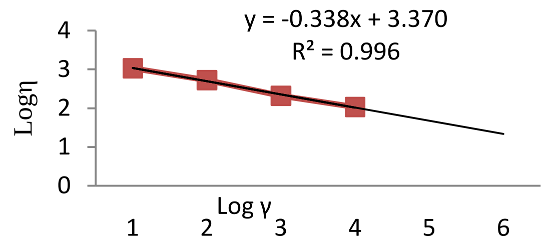

Figure 1: Power Law Plot

Table 3: Power Law Parameters

Power law parameters	Values
N	0.6620
K(mPa.s)	2344.23
R^2	0.9960

The power law parameters; n and k are presented in Table 3. Power law model gave a non-Newtonian behaviour of the samples with power law index (n); 0.6620 which is less than 1 and a correlation coefficient of 0.9960. The power law index shows that the sample is shear thinning. Hence the paint sample produced from jatropha seed oil is said to be a pseudoplastic fluid. The sample being a pseudoplastic paint can be applied by brushing (BASF, 2015).

Consistency index (k) was calculated to be 2344.23mPa.s using the linear equation of the plot. The value of k is the viscosity at 1sec^{-1}. This value can be used for viscosity measurement for comparative purposes. With the known 'n' and 'k' values, the viscosity can be predicted at any shear rate by applying the power law equation. Reformulation of this product to satisfy specific needs, such as appearance, application method among other can be changed with these known values.

IV. CONCLUSION

Power law model was used to fit the log of viscosity and shear rate of washable paint sample produced from jatropha seed oil. The results revealed that the sample studied is highly shear- thinning (pseudoplastic) with power law index of 0.6620. The applicability of the power law model to quantify the shear thinning behavior of washable paint was demonstrated. This work has also demonstrated the ability to determine the characteristics of the paint sample during different stages of paint processing. It has also demonstrated the applicability of power law model in the rheological characterization of paints.

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