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RHEOLOGICAL STUDIES OF CONDUCTING ACRYLIC PAINT

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ABSTRACT:

In this study the conducting acrylic paint were developed by the addition of conducting filler, carbon black, during the mechanical process at highest mixing condition, 10000 rpm for 5 minutes at room temperature. The conducting paint was analyzed in a rotational viscosimeter at different conditions of shear rate and temperature. In the shear rate conditions the carbon black changes significantly the rheological paint behavior, deviating the original pseudoplastic characteristic of acrylic paint. To determine the activation energy the rheological analysis were done at 20°C, 30°C and 40°C, the high amount of carbon black showed lower activation energy at 200 S-1 which is good for the application with a roller.

Keywords: conducting carbon black, rheology, viscosimeter, flow curve

ABSTRACT:

Neste trabalho foi desenvolvido tintas acrílicas condutoras através da adição de carga condutora, negro de fumo, pelo método de mistura mecânica realizada em nas seguintes condições 1000 RPM por 5 minutos. As tintas condutoras foram analisadas através de viscosímetro rotacional a diferentes temperaturas e condições de cisalhamento. A adição de cargas condutoras modificou as características reológicas da tinta, grande quantidade de negro de fumo condutor mostrar baixa energia de ativação a 200 s-1 que são condições ideais para aplicação com rolos.

Palavras-chave: Negro de fumo, reologia, curva de fluxo

1 INTRODUCTION

Organic coatings, particularly paints, constitute one of the most widely employed methods of protection to preventcorrosion of steel. Among the reasons accounting for their widespread use are their low cost, the ease of application and their aesthetic functionality. As a result, it is estimated that approximately 90% of all steel surfaces are protected with paints (BARTON, 1976).

The new generation of paints that employ non-contaminating inhibitors and water as solvent usually suffer from the problem that they do not achieve as good as an anticorrosive performance as the contaminating paints that they are intended to replace. This problem becomes especially critical in sector like the shipbuilding industry where high specification products must be used (BETHENCOURT, 2003).

It is a usual observation that an emulsion paint kept for a long period of time under quiescent condition in a container remains highly viscous. Painters stir it manually, which gradually lowers the viscosity as a function of time. However, if stirring is stopped, viscosity of the same gradually increases with time. Besides paints, many soft materials of immense commercial importance such as toothpastes, concentrated emulsions and suspensions, colloidal gels, industrial slurries, pharmaceutical and cosmetic creams and variety of soft food items such as jam, jelly, mayonnaise, etc., demonstrate time-dependent evolutions of viscoelastic properties that are strongly affected by a deformation field (CIPELLETI, 2000; BONN, 2002; CRISTIANI, 2005).

Behavior of a painting during application is a critical aspect that must be considered in developing a paint formulation to meet final performance targets. In a given application method (roll, spray, curtain, etc.), within a set of process conditions (flow rate, line speed, fluid and air pressure, etc.), rheology is the most important characteristic that governs a paint behavior during the application. Therefore, it is important to understand the impact of paint rheology on its behavior under complex flow conditions encountered during application.

The rheology of paints mainly depends on the nature and concentration of the polymer matrix (SCHOFF, 1988), and determines the performance of the paint during the whole handling cycle, from storage to application and drying (ALEMANN, 2006).

This study reports the rheological behavior of a commercial acrylic water-based paint mixed with conducting carbon black to produces the conducting. This study is part of a research project aimed at evaluating the electromagnetic interference shielding material of different ecological paints employed in the shipbuilding industry.

2 MATERIALS AND METHODS

2.1 Materials

Commercial acrylic paint were kindly supplied by TintasYpiranga S.A. (Brazil) and conducting carbon black XC72 kindly supplied by Cabot (USA) have been studied in this work. A Rotational Viscosimeter, Rheolab QC from Anton Paar,works according to the Searle principlewere used to obtain the rheological information.

2.2 Methods

The conducting acrylic painting were obtained by the addition of conductive carbon black in the acrylic painting by the mechanical mixer in the following condition: 10.000 rpm for 5 minutes in room temperature. The formulation used in this study is showed in Table 1.

Table 1. Formulation of the Conducting Acrylic Paint

Sample	Acrylic paint (phr)	Carbon black (phr)
0	100	0
5	95	5
7,5	92,5	7,5
10	90	10

The rheological characterization was carries out using a shear rate controlled rotational rheometer (Rheolab QC from Anton Paar), coaxial cylinder sensor (inner cylinder diameter 28.93 mm, outer cylinder diameter 30.0 mm, length 24.0 mm, and sample volume 18.7 cm3. The temperature was controlled with an accuracy of ± 1 ◦C by circulating water in the jacket of the outer cylinder arrangement.

Two kind of rheological test were designed to evaluate the samples behavior. In the first test, the samples were conditioned in the temperature test (20oC, 30oC and 40ºC) for 3 minutes in order to obtain the thermodynamic equilibrium. The step-change of shear rate sweep test varying from 0.1 to 800 s-1). The second test were conducted by using a constant shear rate 200 s-1applied for 10 minutes, time enough to reach the steady state value.

The rheological behavior of the non-Newtonian fluid is characterized by using a power law model, as showed in equation 1.

$$\eta = k\acute{\gamma}^{n} \qquad (1)$$

Where k is the flow consistency index, n is the flowbehavior index, and γ'is the shear rate.

3 RESULTS AND DISCUSSION

The flow behavior of material is characterized by the relation between shear stress and shear rate. This curve aredenominate flow curve. The shape of the flow curves indicates the type of flow behavior exhibited by the sample (Newtonian, shear thinning, shear thickening and Bingham plastic), as described by Macosko (1994).

Figure 1 shows the experimental flow curves for the samples at 20°C, and it can be noted the non-Newtonian behavior of the paints. The samples exhibited a shear thinning behavior, because the shear stress increases with the shear rate.

In the present study it was used the power law equation to describe the Non-newtonian fluid. For sample with higher amount of conductive filler, 10 phr, the curve showed the worst relation with the power law model. It can be attributed the tendency to form high amount of aggregates in the paint. This behavior is normally associated with build-up of structure in the complex fluids under quiescent conditions in a deformation field, Green (1948) and Mewis (1979) obtained similar results.

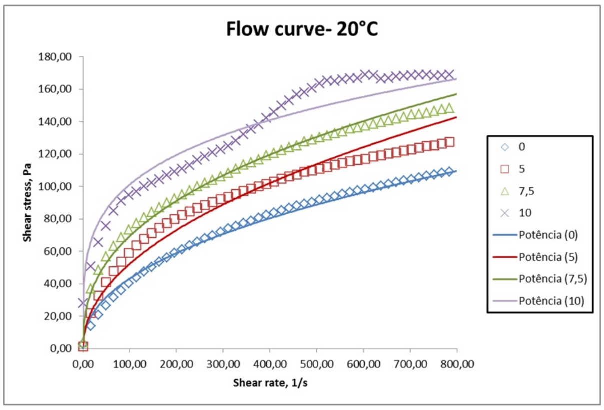

Figure 1. Flow curve for the conductive paints at 20°C

Table 2 show the rheological parameters for the power law model in different temperatures studied. To obtain the best fitted lines, the sum of square errors (SSEs) was minimized. The coefficient of determination, R2 was calculates using R2 = 1-(SSE/SST), where SST is the total corrected sum of squares (WALPOLE, 2002). In all the cases, the power law index, n, is less than 1, which corresponds to a shear thinning fluid (BARNES, 1997). The variation of n as function of the percent of conductive filler can be analyzed by the Table 2. The n parameters increase as the carbon black increase in the painting which indicates that the rheological behavior of the polymer is near the Newtonian behavior.But when the analysis is done in the same concentrationbut varying the temperature it is observed the paint farthest deviation from Newtonian behavior to high amount of filler (10 phr). This probably due the carbon black filler can dispersed the flux energy rotational in the paint.

Table 2. Power law parameters for acrylic paint at different temperatures

T = 20°C			
	k	n	r2
0	5,54	0,56	0,983
5	5,67	0,52	0,984
7,5	11,38	0,61	0,994
10	33,68	0,76	0,929
T = 30°C			
	k	n	r2
0	2,18	0,45	0,999
5	3,96	0,51	0,987
7,5	12,71	0,65	0,985
10	15,76	0,65	0,959
T = 40°C			
	k	n	r2
0	2,12	0,49	0,998
5	4,62	0,58	0,996
7,5	11,54	0,65	0,977
10	10,46	0,56	0,999

The Arrhenius relationship was used to describe the effect of temperature on the activation energy(KAYA, 2005). Activation energy indicates the sensitivity of the viscosity to temperatures changes. Higher activation energy means that the apparent viscosity is relatively more sensitive to temperature.

Figure 2 shows thetemperature dependence of the shear rate viscosity obtained at 600 1/s. The viscosities at different temperature were fitted to the Arrhenius equation (Equation 2), which describes the viscosity exponential dependence over the activation energy of viscous flow, -Ea:

$$\eta = Aexp\left(-\frac{Ea}{RT}\right) \quad (2)$$

Where: R is the gas constant and A the Arrhenius pre-exponential factor.

It is noted in the Figure 2, that the samples with high amount of carbon black, 7,5 and 10 phr were the linear slope reduced compared with the original paint.This behavior will have the activation energy more reduced than is in accordance with the n values. When carbon black is in high amount the paint tends to show the Newtonian behavior.

The lower activation energy, Ea, for the samples with higher amount of filler is interesting to paint with rollers or spray and can have good electromagnetic properties by the good dispersion of filler in the wall surface.

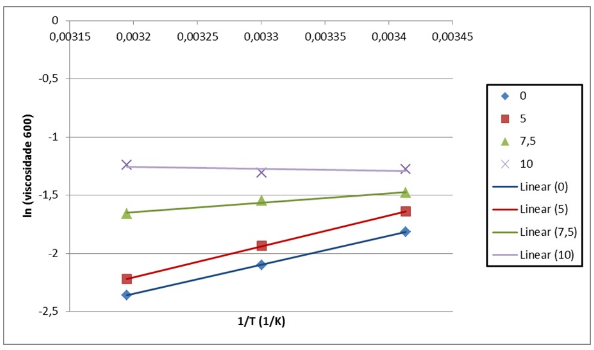

Figure 2.dependence of shear-viscosity on the temperature.

4 CONCLUSIONS

The conducting acrylic paints have changed the rheological behavior showed by the original paint.

The carbon black increases the viscosity and the power law indexof the paint.

The activation energy has been reduced by the carbon black which suggest the best condition for spray proceeds of paint.

5 ACKNOWLEGMENT

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