Correlation between traditional methods for characterisation of sag and levelling of paints and rheological measurements

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ABSTRACT

The viscous to elastic proportion (tan θ) at low frequency (in a frequency sweep) is assumed to be a measure relevant for characterising levelling, and the Newtonian viscosity (zero-shear viscosity) taken from the creep measurements is assumed to be a good measure for the sag resistance. A sag index applicator was used to characterise the anti-sagging properties and a Leneta levelling test blade were used for characterising the levelling properties. This work shows that the Leneta levelling has a linear correlation with the tan-θ (G"/G') value at low frequency (0.2 Hz) for the specific paint system tested. The sagging resistance shows an exponential correlation with the Newtonian viscosity calculated from the creep measurements.

INTRODUCTION

Traditionally rheological characterisation of paint and coatings has been limited to single point measurements like the ICI or Brookfield viscosity. A more in depth characterisation using a rheometer is often not considered worthwhile because it has been difficult to relate many of the rheological parameters to real life properties like i.e. sagging, levelling or thixotropy. In this work the results from a large screening of different rheology modifiers where used to indicate possible correlation between the traditional methods for characterisation of sagging and levelling and viscoelastic measurements on a rheometer. In this work a pure acrylic waterborne trim paint were used as model paint system

Sagging occur when a paint with an unbalanced rheology relative to the thickness of the paint applied to the wall starts to flow under the influence of gravity. Figure 1 illustrates the process.

For Newtonian liquids the velocity of flow, or sag velocity (V_0), are given by[1];

$$V_0 = \frac{\rho \cdot g \cdot h^2}{2 \cdot \eta} \qquad (1)$$

where η is the "zero-shear" viscosity, ρ is the specific gravity of the paint, h is the film thickness and g is the gravity constant. For non-Newtonian liquids (i.e. paints) the viscosity in equation (1) will be an approximation.

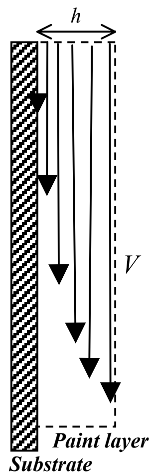

Figure 1. Schematic outline of the sagging process

Levelling is a more complex process than sagging with the surface tension in addition to the viscosity as driving force. Figure 2 gives a very schematic illustration of a brush-applied paint with its characteristic ridges.

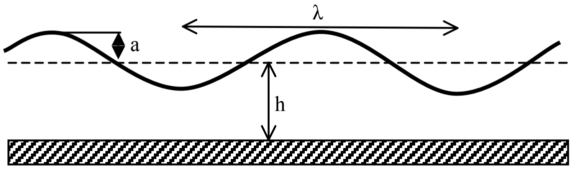

Figure 2. Schematic outline of the levelling process.

Levelling can be described by the Orchard equation[1,3]:

$$a(t) = a(0)\exp\left[-\frac{16\pi^4 h^3 \Gamma t}{3\lambda^4 \eta}\right] \qquad (2)$$

where *a(0)* and *a(t)* are the initial height of the coating ridges (amplitude) and the height after time t respectively, *h* is the coating thickness, Γ is the surface tension, *λ* is the wavelength (distance between ridges) and *η* is the viscosity.

EXPERIMENTAL METHODS

A total of 108 different paints were made based on the same binder system, but with different rheological profiles.

All paints were put through a series of rheological measurements on a Carri-Med CSL-500 rheometer from TA-Instruments. A 4 cm 2º steel cone geometry were used in all measurements. A torque-sweep was done to define the linear viscoelastic area, a frequency-sweep was done defining a "mechanical spectrum" and a creep experiment was carried out to get the relative Newtonian viscosity. Figure 3 shows a typical result from a frequency sweep. The tan θ value used for the correlation evaluation is indicated with the dotted line at 0.2 Hz.

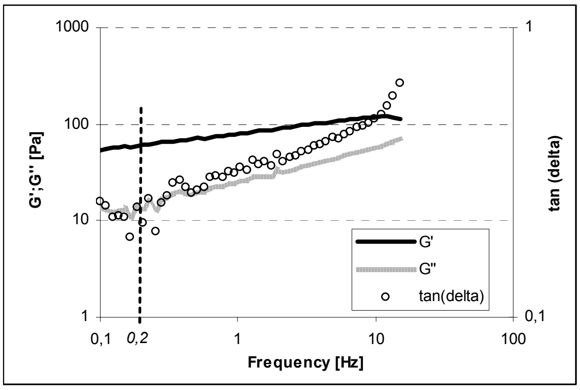

Figure 3. Example of a frequency sweep of a paint with high degree of elasticity (low tan θ value).

Figure 4 shows a typical result from the creep experiment. The stress applied in this experiment was set to 1 Pa, which is said to simulate the stress due to gravity[2]. The resulting Newtonian viscosity was calculated by the instrument software.

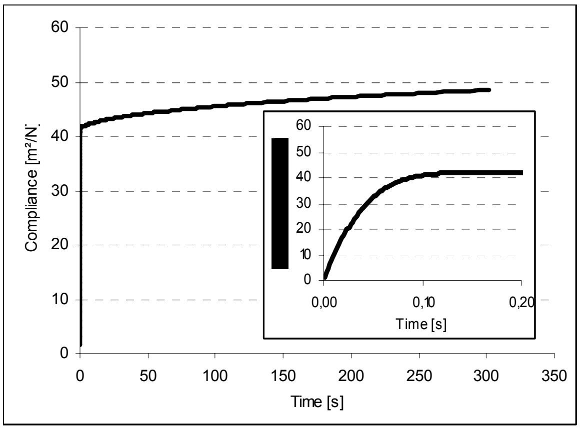

Figure 4. Example of a creep measurement of the same paint as shown in figure 3 (high Newtonian viscosity).

Sagging was measured using a modified version of the standard method ISO 16862:2003 "Evaluation of sag resistance". On a black and white drawdown card a line was drawn across the card using a pen with water-soluble ink, before doing the draw down with the applicator. The ink will migrate through the paint film and follow the paints movement indicating at which film thickness the paint starts to sag.

Levelling was measured using a "Leneta levelling test blade" from the Leneta Company. Drawdowns were evaluated after the paint had dried and compared with "drawdown levelness standard", giving the levelling a value from 1 to 10 where 10 is complete levelling.

RESULTS AND DISCUSSION

For each of the sagging readings (the wet film thickness were sagging starts) the Newtonian viscosity for the corresponding paints was noted. The mean value of all the calculated Newtonian viscosities was then plotted against the wet film thickness. The resulting correlation curve is given in figure 5. These results indicate an exponential correlation between wet film thickness and viscosity. The equation given in (1) shows that one should expect the viscosity to correlate with the square of the wet film thickness. The equation is, however, only valid for Newtonian liquids and is therefore not entirely relevant for the paint system tested here.

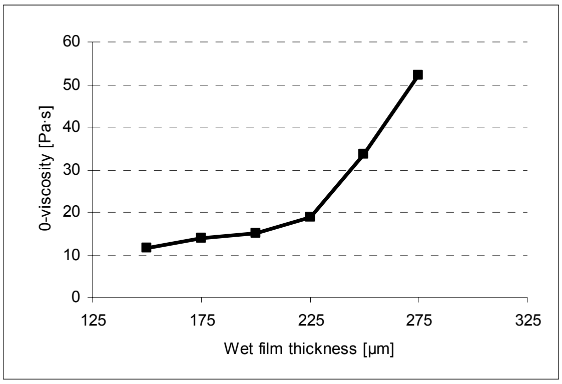

Figure 5. Correlation between wet film thickness and Newtonian viscosity.

For all the paints having the same Leneta levelness reading, the mean value of the corresponding tan θ value (at 0,2 Hz) were plotted giving the correlation curve shown in figure 6. The author has found no theory that specific argues the relationship between elastic properties and levelling of paints, but Verkholantsev[1] emphasise the importance of surface elasticity of the liquid with respect to levelling.

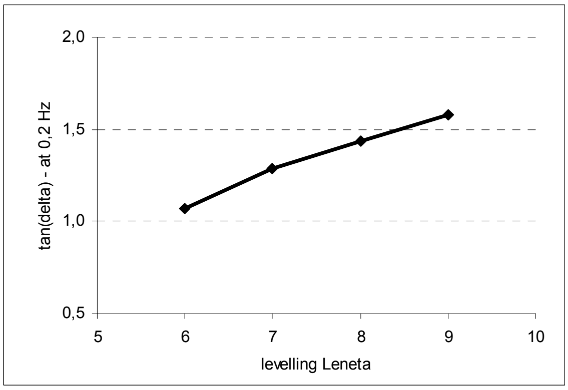

Figure 6. Correlation between Leneta levelling and tan θ.

It is important to emphasise that the experimental error not could be properly assessed, and that this introduces a degree of uncertainty with respect to the results. A more thorough investigation to confirm these results should also include different paint system. The rheological measurements must be regarded as valid only for approximately equal paint systems (i.e. same binder) that has the same drying and open time.

CONCLUSION

This work demonstrates a exponential correlation between measured sagging resistance and the Newtonian viscosity calculated from a creep experiment and a linear correlation between measured Leneta levelling and the tan θ value.

REFERENCES

1. Verkholantsev, V. V. (1999), "Rheology of paints and applications", European Coatings Journal, 06/99, 48-55.

2. Clayton, J. A., Whitehead, T., "Rheology – Back to the basics", European Coatings Journal, 11/99, 20-31.

3. Barnes, H.A. (2000), "A Handbook of Elementary Rheology", The University of Wales.