Application Report

Paper wettability by water-based inks

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Industry sector:	Paints, inks
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Drop Shape Analyzer – DSA100

Force Tensiometer – K100

Methods:

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How patient is paper?

Abstract

As a result of the increasing abandonment of the use of organic solvents in paints and inks and use of water instead the wettability of the paper has become an important quality assurance factor. In an investigation the surface free energies of the main constituents of paper and their general wettability were demonstrated by using wetting envelopes, a surface free energy plotting method. The positions of the surface free energy data of water and a characterized color concentrate with regard to the wetting envelopes provided information about the wettability of all paper constituents by both liquids. In this way it was possible to determine the quality of the concentrate itself and the influence of diluting it with water.

Method

Water-based paints and inks are continually gaining ground. The manufacturers of such inks are normally more concerned with the wettability of solid printed substances than is the case with organically based inks. In the study presented here a KRÜSS customer wanted to know how the wettability of the main constituents of paper – cellulose, kaolinite and titanium dioxide – is affected by an ink blend. At the same time a comparison was to be made with their wetting by pure water in order to estimate the alterations to the wettability of the paper caused by diluting the ink.

In order to be able to evaluate the wettability of the most important constituents with the ink blend and pure water at a glance the presentation of the so-called wetting envelope seems to be suitable. In this technique the polar and disperse fractions of the surface free energy of the solids are determined first. By using the selected calculation method for the surface free energy – for example Owens-Wendt-Rabel-Kaelble – it can then be calculated at which polar and dispersive fractions of the wetting liquid would produce a theoretical contact angle of 0°, i.e. complete wetting. This produces a bow-shaped curve, below which complete wetting can be expected and above which the wettability decreases as the distance from the curve increases. The wettability of each individual constituent by particular liquids – in our study an ink blend and water – can be read off from their position in the wetting envelope diagram.

Experiment and results

To solve this problem two instruments from different KRÜSS instrument families were used: the K100, a mechanical tensiometer, and the DSA100, an instrument for drop shape analysis. The two extenders, titanium dioxide and kaolinite, were present in powder form which is why the surface free energies of these two constituents were measured by the K100 using the Washburn method. There, use is made of the fact that the sorption rate of a liquid depends upon the contact angle, among other things, so that this can be determined if the capillarity of a bulk powder is known. The capillarity is again measured with an optimally spreading liquid that forms a contact angle of 0°. If the surface tensions and their polar and disperse fractions of all the liquids used are known then, just as in the optical contact angle method for flat surfaces, the surface free energy of the powder can be calculated.

Cellulose, the third constituent of paper, was present as a compressed solid; in this case the surface free energy was determined by using the DSA100 to make contact angle measurements with the test liquids ethylene glycol, 1,5-pentanediol and diiodomethane. Wetting envelopes could then be produced for all three samples:

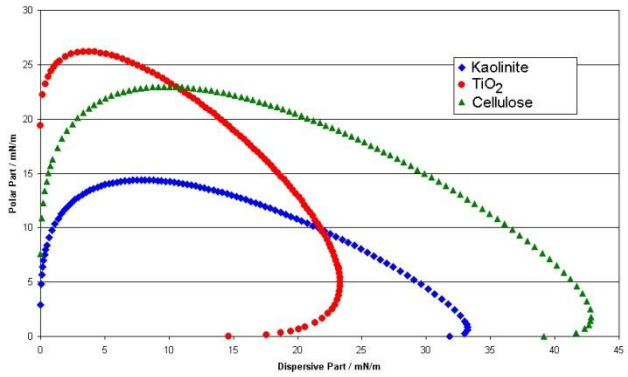

Fig. 1: Wetting Envelopes of the paper constituents

However, in order to be able to assess how the ink blend wetted the three constituents it was necessary to characterize it – with further measurements using the DSA100. The first necessity was to determine the surface tension of the ink blend. Due to its high viscosity, at which many of the conventional surface tension methods would be useless, we selected the pendant drop method in which the image of a suspended drop is analyzed. In equilibrium such a drop forms – even with highly viscous liquids – the ideal Young-Laplace shape, which is determined by the surface tension. If the image scale is known then the surface tension of the drop liquid can be measured exactly and without any problems. For the ink blend a value of 30.58 mN/m was obtained for the surface tension.

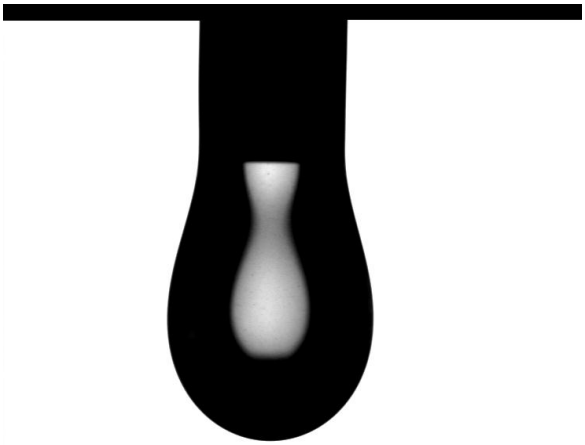

Fig. 2: Profile of a pendant drop

It was then necessary to determine the polar and disperse fractions of this value. This was done by measuring the contact angle of the ink blend on the purely disperse solid PTFE. The following values were obtained:

σ [mN/m]	Contact angle on PTFE [°]	σ^D [mN/m]	σ^P [mN/m]
30.58	60.9	22.66	7.92

Tab. 1: Surface tension of an ink blend

It was now possible to determine the position of this liquid with respect to the three wetting envelopes and to compare it with the position of the water:

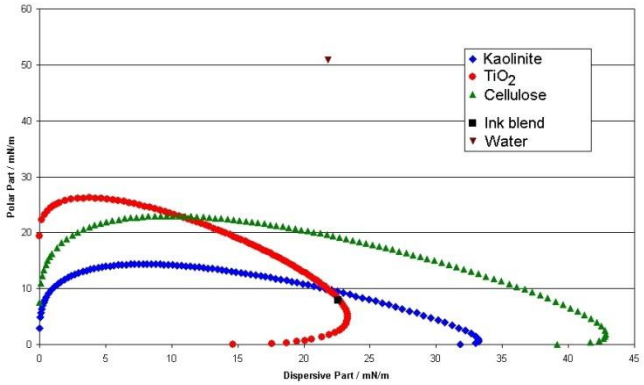

Fig. 3: Wettability by ink blend and pure water

It can be seen that the ink blend wetted all the three paper constituents perfectly. Although the distance to the surrounded curve is reduced from cellulose through kaolinite to titanium dioxide, even with titanium dioxide no problems with wetting difficulties are to be expected.

The position of liquid water with respect to the wetting envelopes is also shown. It can be clearly recognized that water has poorer wetting properties than the ink blend – for all three paper constituents water is a long way outside the optimal wetting range. This means that the wetting behavior of the ink itself cannot be criticized. Only as its dilution with water increases can the ink solution move outside the optimal wetting range and the application of the diluted ink to the paper may not proceed optimally.

Summary

By using powder contact angle measurements with the Force Tensiometer – K100 and optical contact angle measurements with the DSA100 the surface free energies of the main constituents of paper – cellulose, kaolinite and titanium dioxide – could be characterized and shown as an arrangement of three wetting envelopes. The polar and dispersive fractions of the surface tension of the water-based ink concentrate were also measured by the pendant drop method and contact angle measurements. The position of the result within the assembled wetting envelopes proved the good wettability of all the paper constituents by the ink blend. By a comparison of the ink with pure water it could be shown that water wets paper much worse and that possible loss of quality when applying the diluted ink is not caused by the quality of the ink blend, but could be caused by the wetting properties of the water.