

# Application Report

## Characterization of viscous ink pastes

Application report: AR239e  
Industry section: Printing  
Author: [short form e.g. NH or JC]  
Date: 12/2003



Drop Shape Analysis System  
DSA10



Force Tensiometer – K100

Method:



Keywords: Printing, surface free energy, wetting, adhesion, viscous ink, fountain solution

## Surface Energy Characterization and Adhesion Properties of High Viscosity Ink Pastes

### Abstract

Printing processes, such as lithography, are greatly affected by surface properties such as surface and interfacial tension, surface energy, and adhesion. Efficient uptake, transport, and adhesion of ink pastes onto various surfaces are governed by surface energy, given by the polar and dispersive properties of both substrates. The lithographic process utilizes print plates designed to have print and non-print surfaces. Fountain solutions are used for the purpose of blocking the non-print surfaces from accepting ink. The print surfaces of the plate are expected to accept ink and transfer it to a “blanket,” or rubber roller, which transfers the ink onto paper or other substrate. To study these types of surface interactions, liquids are typically characterized by classical methods of DuNouy Ring or Wilhelmy plate. However, in this study, two ink pastes are characterized by treating the samples as solid surfaces, using the Fowkes two-component method of surface free energy, and adhesion properties of the inks to several surfaces are discussed.

## Experimental section

Two ink pastes from an ink manufacturing company were studied: INK A, which showed very good adhesion properties in application, and INK B, which was not transferring properly to the print blanket, thus causing poor print quality. The inks were characterized for overall surface energy and surface polarity in both the original inks, and when emulsified with 15 wt% of fountain solution. Emulsions of the pastes and fountain solutions were studied because they contact one another in the printing process, and it is known that the fountain solution will act to emulsify the paste. As neither the original paste, nor the emulsified pastes were of low enough viscosity to be tested as liquids, the samples were tested for surface energy as solid surfaces. Glass slides were separately coated with both the pastes and emulsions, and contact angles were obtained with the Krüss Drop Shape Analysis System DSA10. Results show the average of five drops of both diiodomethane and water on the samples (see table 1).

Ink Paste	Contact Angle with Water (degrees)	Contact Angle with Diiodomethane (degrees)
A	92.6	43.5
B	90.4	61.8

Table 1: Contact angle with water and diiodomethane on ink pastes

Contact angles with diiodomethane and water after emulsifying each paste with 15 wt% of fountain solution are shown in table 2.

Ink Emulsion	Contact Angle with Water (degrees)	Contact Angle with Diiodomethane (degrees)
A (emulsion)	87.0	44.6
B (emulsion)	81.0	62.0

Table 2: Contact angle with water and diiodomethane on ink emulsions

The Fowkes two-component method (see Application Note 306, "So You Want to Measure Surface Energy," [www.kruss.de](http://www.kruss.de)) of solid surface energy was applied, yielding the following surface energy values of both the original and emulsified pastes (see table 3).

Paste	Overall Surface Energy (mJ/m <sup>2</sup> )	Polar Component (mJ/m <sup>2</sup> )	Dispersive Component (mJ/m <sup>2</sup> )	Surface Polarity (%)
A	38.02	0.21	37.81	0.56
B	29.36	1.82	27.54	6.19
A (Emulsion)	38.27	1.04	37.23	2.72
B (Emulsion)	32.39	4.97	27.42	15.34

Table 3: Surface energy values of both the original and emulsified pastes

Results from the original inks show two major differences in their surface properties:

The overall surface tension of INK B is lower than that of INK A. This implies that INK B may wet surfaces more easily than A. However, INK A has a much lower surface polarity (0.56 %) than that of INK B (6.19 %). So though INK B may appear to wet better, it actually will not "adhere" as well as INK A to low polarity (hydrophobic or lipophilic) surfaces – such as print blankets.

When 15 wt% of the fountain solution were mixed with the original ink pastes, both emulsions showed increases in overall surface energy, though the Emulsion B increase was more significant. However, differences in surface polarity were much more extenuated in the emulsion samples. Both inks show increases, but customer INK A showed a dramatic 9 % increase in surface polarity. Results show that the wetting properties of the two inks become more similar by the addition of the fountain solution, while their relative abilities to adhere to low polarity surfaces become more separated.

To better understand why the diluted fountain solution were having such effects on the surface properties of the two ink pastes, the overall surface tension, with polar and dispersive components, was tested using the Wilhelmy plate method on a Krüss Force Tensiometer – K100. Measurements of the liquid against poly(tetrafluoroethylene) yielded the polar and dispersive components of the overall surface tension by applying the Fowkes equation to the contact angle results. The average of duplicate experiments is shown in table 4.

Surface Tension Data for Diluted Fountain Solution (29.96 kg/m <sup>3</sup> )					
Test #	Overall Surface Tension (mN/m)	Contact Angle on PTFE (degrees)	Dispersive Component (mJ/m <sup>2</sup> )	Polar Component (mJ/m <sup>2</sup> )	Surface Polarity (%)
Average	38.46	79.5	28.71	9.75	25.35

Table 4: Surface tension data for diluted fountain solution

First, the fact that the overall surface tension of the diluted fountain solution is 38.46 mN/m explains why adding it to the A paste (original surface energy = 38.03 mN/m) only increases its surface energy slightly, while adding it to the B paste (original surface energy = 29.36 mN/m) increases the B paste's surface energy more significantly. Second, the fact that the surface polarity of the fountain solution, which adheres to the non-print surfaces to prevent paste from adhering to these spots, is only 25.35 % suggests that the emulsified B paste (at 15.34 %) may have problems staying only on the print surfaces.

This study also included surface energy characterization with polar and dispersive components of four surfaces (print surface, non-print surface, new blanket, and used blanket) for comparison between INK A and INK B adhesion using the Fowkes/Dupre expression (see table 5).

Surface	Overall Surface Energy (mJ/m <sup>2</sup> )	Polar Component (mJ/m <sup>2</sup> )	Dispersive Component (mJ/m <sup>2</sup> )	Surface Polarity (%)
Print Surface	42.26	1.61	40.65	3.81
Non-Print Surface	69.82	42.57	27.25	60.97
New Blanket	14.14	0.08	14.06	0.54
Used Blanket	35.66	4.15	31.51	11.65

Table 5: Surface energy values on printing plate on blanket

Results show that Paste A and Emulsion A should (and do) adhere best to the print surface because the polarity of the ink and the print surface match more closely (0.55 and 2.72 % for INK A versus 6.2 and 15.34 % for the problematic INK B), and likewise yield higher adhesion energies using Fowkes/Dupre theory (see table 6).

Adhesion Energy Values in mJ/m <sup>2</sup>				
	Print Surface	Non-Print Surface	New Blanket	Used Blanket
A	79.57	70.18	46.37	70.89
B	70.34	72.39	40.11	64.41
A (emulsion)	80.39	77.01	46.33	72.65
B (emulsion)	72.43	83.76	40.51	67.87
Fountain Solution	76.25	96.69	41.92	72.88

Table 6: Adhesion energy values

The non-print surfaces should not present problems because the pastes and emulsions have little chance to displace the fountain solution from the non-print area due to its high polarity (60.97 %). The adhesion energy between the non-print area and the fountain solution is much greater than between any of the pastes or emulsions and the non-print surface.

The new blanket was studied which was extremely low in overall surface energy

(14.14 mJ/m<sup>2</sup>) and surface polarity (0.54 %). Therefore, adhesion to the blanket is going to be best for a low surface polarity, high overall surface tension liquid. As expected, the overall surface polarity of the blanket matched best the surface polarity of the competitor ink; hence the better observed printing results.

The used blanket's performance is expected to decrease with use because the surface appears to become much more polar, and higher in overall surface energy, with use.

Overall, the surface polarity of the customer's INK A was high compared to their competitor. It was concluded that the problematic ink needed to be reformulated to decrease surface polarity and increase overall surface tension for better adhesion performance.

## Summary

The surface properties of two ink pastes were characterized to understand their performance on several different surfaces. Because of the high viscosity of the pastes, a different approach was developed to study the surface energy components by treating the samples as though they were solids, and applying the Fowkes two-component surface energy method to observed contact angles. Results confirmed what the customer was observing: that one ink was performing better than the other, and, more importantly, served as a directional recommendation on how their particular formulation could be altered to improve performance.