Application Report

Characterization of an Offset Printing Process

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Industry section: Printing

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Drop Shape Analysis System DSA10

Method: 

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Applications of Sessile-Drop and Pendant-Drop Techniques in Offset Printing Technology

Abstract

As many types of interfaces are involved in offset printing parameters like wetting, spreading, surface and interfacial tensions as well as surface free energies play major roles in success or failure of such process.

Main features that are influenced by these parameters are:

- water uptake of ink from the fountain solution (lowers viscosity to help making transport of the ink easier)
- spreading and adhesion of the ink film on/to the printing areas of the printing plate
- spreading and adhesion of the fountain solution on/to the non-imaging areas of the printing plate
- separation of ink and fountain solution

These processes are not independent of each other and have to be balanced very carefully.
Some of these aspects shall be covered in this application report using the KRÜSS Drop-Shape-Analysis-System DSA10.

The printing ink and its components

Due to the fact that special rheological characteristics (high viscosity, pseudoplasticity) are optimized towards non-fluid behavior surface tension cannot be measured with classical methods such as ring or plate. The pendant drop technique allows measurements of even very high viscous systems if a drop at the tip of a syringe´s cannula can be formed. The equilibrium droplet curvature is directly related to exactly one value of surface or interfacial tension.

Resins

Usual alkyd resins used as basic binders for inks have surface tensions between 30 and 35mN/m. Figure 1 shows a typical example of SFT vs. time measured on a usual alkyd resin (SFT in equilibrium is 34.48+/-0.01mN/m).

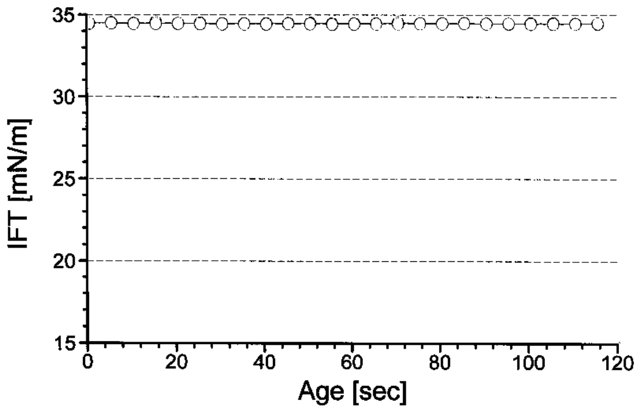


Fig. 1 : Surface tension vs. time of alkyd resin measured by the pendant drop technique

Oils

Oils are used as extenders and to adjust viscosities in offset inks. A broad variety of natural or synthetic oils is used depending on the application of the ink. Standard oils have surface tensions between 25 and 30mN/m. Figure 2 shows a typical sample with 27.58+/-0.02mN/m.

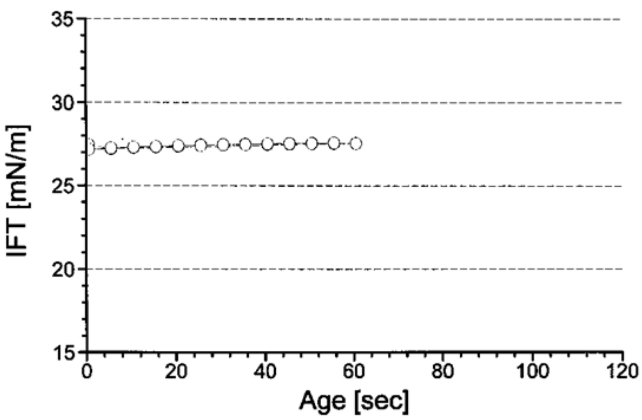


Fig. 2 : Surface tension vs. time of oil measured by the pendant drop technique.

For waterless offset printing (dryography) silicon oils are emulsified directly as pseudo-fountain solution in the ink. Their SFT varies between 18 and 22mN/m depending on chain length of the poly-(dimethylesiloxane).

Inks

Looking at the results above and taking into account that besides the substances mentioned also a huge amount of pigments and additives give a complete ink it is obvious that inks can have surface tensions as low as 20mN/m or as high as 35-40mN/m. The value is dependent on the individual recipe of the ink. Especially pigments often play unpredictable roles when coated with enhancers for particle stabilization and pourability. Figure 3 shows a typical example of an alkyd-based standard offset ink (surface tension in equilibrium is 29.55+/-0.01mN/m).

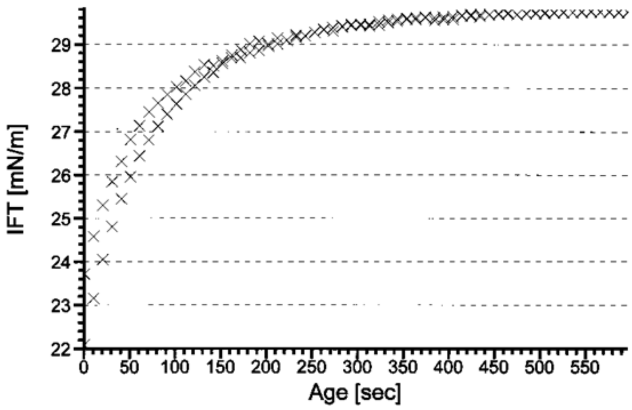


Fig. 3: Surface tension vs. time on a usual offset printing ink measured by pendant drop technique

For dryography (no fountain solution needed) silicon oil is added as intrinsic wetting agent. It is emulsified in the ink. Due to high shear rates this emulsion can break and release the silicon oil. It protects the non-imaging areas from the ink. Only the silicon oil with its small surface tension is able to spread on the extremely low energetic surfaces of the waterless plates (see section about waterless plates below). Figure 4 shows a typical example of a silicon-containing ink for dryography (surface tension in equilibrium is 19.78+/-0.03mN/m).

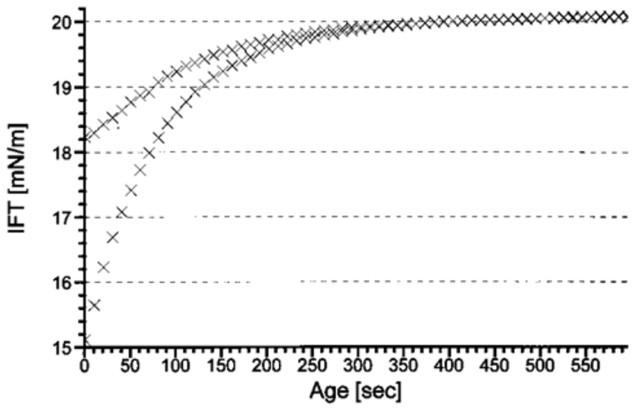


Fig. 4: Surface tension vs. time on a dryography printing ink measured by pendant drop technique

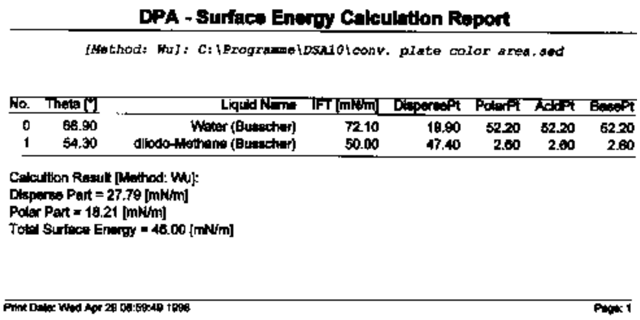
Fountain Solution

The main task of fountain solutions is to wet the non-imaging areas completely so they are protected from ink. This can be obtained by lowering the surface tension of the fountain solution below the surface free energy of the non-imaging areas (the lower the better in this case). On the other hand ink must spread on imaging areas and displace (at least in the first stage) a film of fountain solution on these areas. The higher the surface tension of the fountain solution and the lower the interfacial tension between ink and imaging areas, the better the second condition is fulfilled. Especially the replacement of isopropanole (the substance lowering the surface tension of water which is the main component of fountain solutions) due to environmental reasons brings up problems in dynamic behavior. Surface tensions (static) of fountain solutions can vary from as high as 70mN/m (near the SFT of pure Water) to as low as under 30mN/m. But even a value of 30mN/m in the static regime does not guarantee low surface tension when subjected to dynamic applications. A careful choice of IPA replacing additives is usually optimized with KRÜSS Bubble Pressure Tensiometers.

Printing Plates

Since offset printing is a flat printing process imaging and non-imaging areas are separated by their wetting and adhesive performance and the cohesion of the ink.
In common offset printing the imaging areas consist of photocrosslinked polymers (acrylates etc.) with surface free energies similar to the surface tension of the ink. The first wetting is determined by the adhesion and wettability between these areas and the ink. Cohesion of the ink on top of the ink-layer on these areas keeps it in place. The non-imaging areas usually are etched aluminum covered with a monolayer of a desensitizer. This arrangement keeps them wetted by the fountain solution which repels the ink.

Figure 5 shows a typical result sheet for measurement of the surface free energy calculation according to Wu for the imaging areas of a conventional offset printing plate.



DPA - Surface Energy Calculation Report

[Method: Wu]: C:\Programme\DSA10\conv. plate color area.sed

No.	Theta [°]	Liquid Name	IFT [mN/m]	DispersePt	PolarPt	AcidPt	BasePt
0	66.90	Water (Busscher)	72.10	18.90	52.20	52.20	52.20
1	54.30	diiodo-Methane (Busscher)	50.00	47.40	2.60	2.60	2.60

Calcultion Result [Method: Wu]:
Disperse Part = 27.79 [mN/m]
Polar Part = 18.21 [mN/m]
Total Surface Energy = 46.00 [mN/m]

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Fig. 5: Report of the surface free energy calculation for the imaging areas on a conventional offset printing plate

In contrary to the facts mentioned above dryography does not use a separate fountain solution. The imaging areas are very similar to that used in standard offset printing. The surface free energy is similar to the surface tension of the inks basic formulation without silicon oil. So the base ink is able to adhere to the imaging areas after been split from the silicon oil. The non-imaging areas in dryography have extremely low surface free energies (the lower the better). These areas are produced by special treatment of the alumina base plate with silanating agents and/or fluorinated resins sometimes in combination with textural effects (lotus flower effect). These areas are wetted only by the silicon oil. The base ink is repelled.

Table 1 shows a comparison of the surface free energies (acc. to Wu) of a standard offset printing plate (not yet desensitized) with a good and a bad dryography (WLP) plate.

Sample	SFE (mN/m)	SFE dispersive Part (mN/m)	SFE polar part (mN/m)	com-ment
conv. plate imaging area	46.0	27.8	18.2	not desen sitized
conv. plate non-imaging area	62.1	21.8	40.3	
WLP 1 imaging area	57.4	28.5	28.9	good WLP
WLP 1 non-imaging area	14.4	11.1	3.3	
WLP 2 imaging area	49.4	38.4	11.0	bad WLP
WLP 2 non-imaging area	18.9	11.8	7.1	

Table 1

WLP 2 does not work as well as WLP 1 due to lack of ink repellency on the non-imaging areas and lower ink receptivity on the imaging areas.

The results above are achieved simply by measuring advancing angles with water as well as with diiodomethane as shown in figure 6.

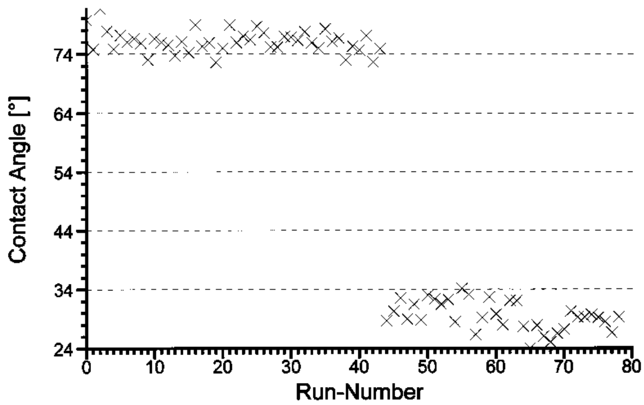

Fig. 6: Contact angle of water (average 76.6+/-0.28°) and diiodomethane (average 30.0+/-0.41°) vs. run number

Interfacial Interactions

Not only surface tensions and surface free energies are necessary to optimize ink transfer, separation of ink and fountain solution, wetting and repellency of the plate by the ink or fountain solution. Especially interfacial tensions play key roles in offset printing technology.

Interface Ink/Printing Plate

A good adhesion and wettability can be deduced from simply looking at the surface tension of the ink and the surface energy of the imaging areas. The lower the difference (the smaller the interfacial tension), the better the interaction between these two phases and the easier a film of fountain solution can be replaced.

Interface Fountain Solution/Printing Plate

Non-imaging areas should be wetted by fountain solution completely. Since the non-imaging areas are very high-energetic this is achieved by lowering the surface tension of the fountain solution under the surface free energy of the plate's non-imaging areas. On the other hand a film of this solution should be easily replaced by the ink. Looking at this aspect the interfacial tension between imaging areas and fountain solution should be larger than the one with ink.

Interface Fountain Solution/Ink

This is probably the most complex interface. On one hand a certain water uptake by the ink (emulsion water in oil) is wanted to achieve good handling features of the ink (lower viscosity). For this purpose the interfacial tension between ink and fountain solution must not exceed a value of approx. 10mN/m (as a rule of thumb), the lower the better. On the other hand an emulsion of ink (oil) in fountain solution (water) is definitely not wanted otherwise tinting occurs. So interfacial tension should not fall below 0.5 to 1 mN/m. If the ink is able to form a droplet in the fountain solution, this value is accessible via pendant drop measurements. Typical results are 1.1 to 2.8mN/m. If the density-difference of the two phases is lower than 0.01g/cm^3 and the ink tends to show pseudoplastic behavior a direct measurement might not be possible (bad reproducibility). Problems like this can be circumvented by not directly measuring the interfacial tension but taking the contact angle vs. time curve into account. For this technique a very thin film of ink on a glass-slide is produced by blade coating. A droplet of the fountain solution is carefully placed onto this 'solid' and contact angle vs. time is monitored. Figure 7 shows a typical measurement performed this way.

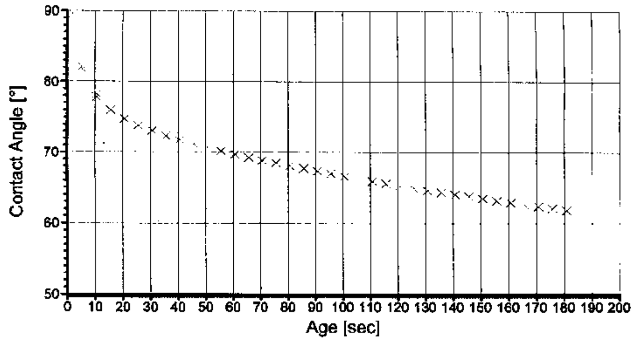

Fig. 7: Contact angle of fountain solution vs. time on an ink film.

Table 2 shows the results of contact angle measurements in comparison to ink constitution. The additive already included in sample 1 lead to tinting, samples 2 to 4 showed even worse behavior. The effect seems to be rather small but significant. This is due to a monolayer of an enhancer the inks pigment is coated with.

sample number	comment	contact angle (° after 100s)
-0-	without additive	66.6+/-0.05
-1-	low concentration additive 1	64.4+/-0.14
-2-	high concentration additive 1	63.2+/-0.50
-3-	low concentration additive 2	62.8+/-0.35
-4-	high concentration additive 2	62.8+/-0.25

Table 2