The Investigation of the Effect of Liquid-Absorbing Capacity of Rough-Surfaced Papers on the Densitometric Values of Printed Inks

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In general, the inks printed on rough-surfaced papers by offset printing methods are physically dried spontaneously. These inks are oil-based, and a certain absorbency of the papers is required for the inks to dry. On the other hand, the liquid-absorbing capacity of the papers is determined by the rate and nature of paper ingredients (e.g, cellulose, paper additives, and filling materials). No lustering process (e.g., coating or calendering) was performed on the surface of these papers. Therefore, these kinds of papers have a porous media with micro-capillary tubes in their structures.

In the present study, white and dark book paper and newspaper were chosen as best examples of rough-surfaced papers. These papers were prepared in a conditioning room in a relative humidity of 65% at 23°C. Then, the following tests were performed on the papers: Cobb 60 liquid absorbing, ash, surface roughness, air permeance, thickness, and grammage. Background prints produced using IGT printing test equipment, which gives a force value of 300 dyn/cm^2, were taken on the surfaces of the papers with oil-based black ink. Density measurements and their evaluations were performed at certain intervals until complete drying was obtained. Photographs of the paper-ink interface were taken, and the depth of absorbance of the ink was determined. Finally, suggestions were reported for the optimum printability of the ink on rough-surfaced papers.

Penetration of Ink into Porous Papers

In general a porous substance is a solid having holes inside. Most natural and synthetic substances are of a porous nature. A piece of chalk or cotton and a slice of bread are examples of porous substances. Uncoated white and dark papers are accepted as porous substrates. Most suitable examples of these papers are news-

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paper and book papers. The holes in the structure of these papers are sometimes related to each other, showing a uniformity. Fluids can only flow from a porous substance if the holes have an homogenous pattern. The physical drying of oil-based offset printing inks on paper substrates is a good example of a liquid flow in a porous media. There is no mathematical model fitting to the liquid fluidity in all porous medium. Therefore, there are no standard data related to horizontal and vertical absorption of ink in the drying period.

The complete drying of oil-based offset inks based on the physical conditions sometimes takes a few days. For example, sometimes when we hold the daily newspaper in the morning, we may see that the substance starts to liquify in our hands. In offset printing, the absorption of ink into paper starts approximately in a duration of a millisecond while it passes between blanket container and printing container.

In this duration, the paper stays at the printing pressure. Then, the absorption continues because of the wetting and sticking effect of ink. This main starting pattern is the same as the other printing procedures and the different inks. Paper undergoes an elastic deformation under the pressure. Filtration of ink into the paper occurs by the effect of elastic returning of paper fibres. During the printing pressure, the gloss of printing decreases. One reason for this is the filtration of carrier, and another reason is that the carrier leaves a film with pigment at the background. This can be experimentally monitored by a glossmeter.

The ink pigment particulates are generally in a size of 1 to 3 micrometer. Although the voids between some fibres are below half micrometers, this measure is smaller than the small holes between most of the paper fibres. When the ink is squeezed into the big holes at the surface fibres and also when it somehow flows into produces a stoper with pigment at the surface.

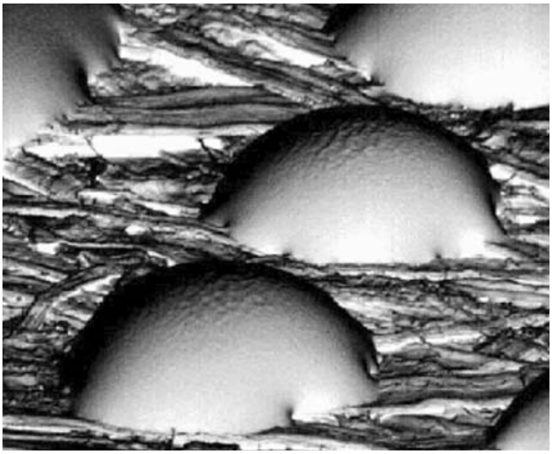


Figure 1. Ink drops at the surface of paper.

In order for ink to dry, pigment and substrate should be absorbed into a certain deepness. However, excess absorption can result in a print-through problem. The occurrence of print-through means that the paper is very rough and that the pigment particles reach the other face; this can mostly occur in the printing of newspaper. The penetration of pigments into paper is very difficult, but most of the carrier is absorbed.

Capillary and Diffusion Models for Porous Media

Penetration of a liquid flowing under its own capillary pressure in a horizantal capillary, or in general, where gravity can be neglected, is theoretically described by the Lucas-Washburn equation:

$$l^2 = \frac{(\gamma_{LG} \bullet r \bullet t \bullet Cos\theta)}{(2 \bullet \eta)} \pm \frac{(r^2 \bullet d \bullet g)}{(8 \bullet \eta)}$$

Where l = penetration distance after time t, r = pore radius, γ = surface tension, θ = contact angle, and η = liquid viscosity. Alternatively for the purpose of these experiments it will be more convenient to employ the volume V, of liquid penetrating into the porous structure after time t.

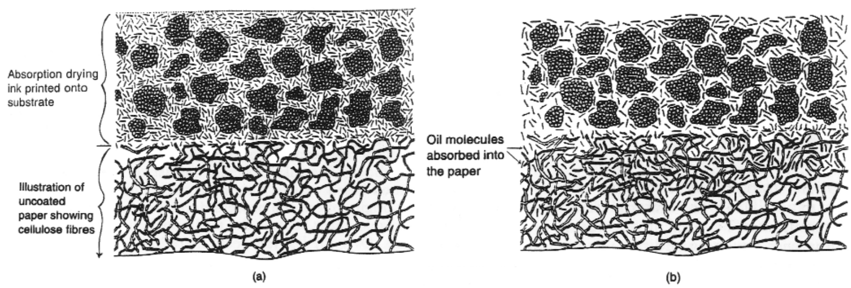


Figure 2. Absorption-drying mechanism:
(a) ink just printed; (b) ink nearly dry.

These concepts are modeled in the Walker-Fetsko ink transfer equation:

$$y = A[bB + f(x - bB)]$$

where: $A = 1 - e^{-kx}$ (fraction of contanct)
$B = 1 - e^{-x/b}$ (fraction of immobilized)
y = amount of ink transferred to paper
x = amount of ink on printing plate
k = rate at which contact is achieved with increasing ink on plate
b = maximum amount of ink that can be immobilized in the paper
f = fraction of free ink film that splits and stays with the paper

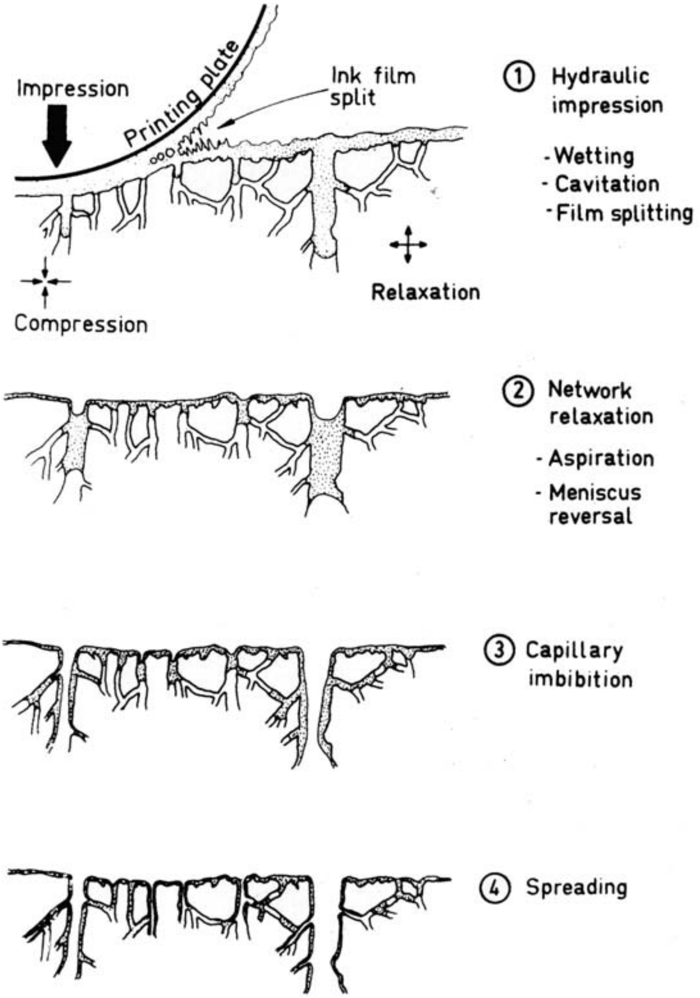


Figure 3. A simplified model of ink impression and absorption.

The following parameters affect the ink absorption in the proceeding stages of the absorption:

- Viscosity of ink
- Stickiness of ink (tack)
- Physical and chemical properties of raw materials in the ink formulation
- Porosity and homogenity of paper
- Physical conditions applied prior to and after printing
- The behavior of the raw materials in the paper structure during the absorption
- The printing pressure and the time at which the paper stayed under pressure

The oil-based ink which is transferred into paper from blanket by the effect of printing pressure starts to diffuse in the horizontal and vertical directions.

Figure 4. Cellulose fibers, magnified 150×.

Materials

In the present study, 50-g/m^2 newspaper and 60-g/m^2 dark book paper were obtained from Seka paper company, and 80-g/m^2 white book paper was obtained from Aklim paper company. An IGT offset test printing machine was used. During the test an IGT ink pipette was used in the ink measurements, and for the densitometric measurements of our printing, a Gretag Macbeth D19C densitometer was used. Sun Chemical oil-based offset printing ink was used as a printing ink.

Table 1. Technical properties of printing substrates.

Samples:		**White book paper**	**Dark book paper**	**Newspaper**
Grammage	g/m^2	78	61	51
Thickness	μm	93	121	90
Ash	%	25.3	3.6	3
Porosity	ml/d	550	300	180
Whiteness (in front)	%	81.69	70.97	50.9
Cobb (in front)	g/m^2	16	13	10

In the present study, the printing ink and substrates were kept at 23ºC for two days. The relative humidity was 65. During the printing, 1.5 ml ink was used by means of an IGT ink pipette for each printimg sample. Then, the ink transfer was carried out at a pressure of 300 Nm. Each print was measured at the following time increments after the printing procedure: 0 minutes, 10 minutes, 30 minutes, 1 hour, 2 hours, 6 hours, 1 day, and 2 days. The total of eight measurements were taken continuously from the same points.

Table 2. Composition of ink (Sun Chemical) used in the test print.

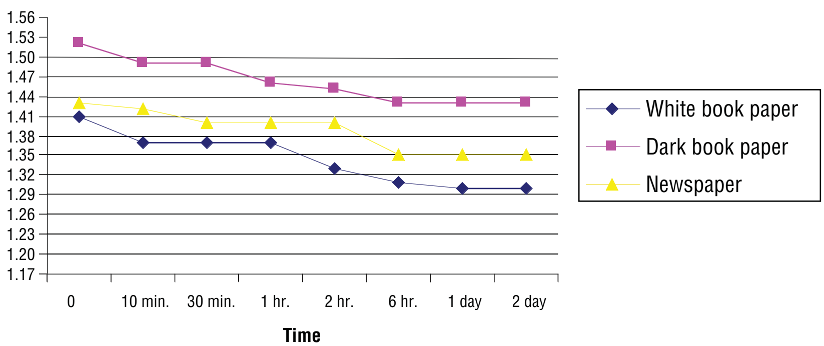
Organic pigments	12–19
Rosin modified phenolic resins	18–27.5
Vegetable-based oils	5–10
Mineral oils	22–30
Driers	1.5–3.5

Results and Discussion

Following measurements taken over two days from the three porous-surfaced paper substrates printed with an oil-based offset ink drying by physical absorption, it was observed that total drying (densitometric stability) occurred after two days.

Because the white book paper had an excess amount of filling material (25.3%), the densitometric stability, which was based on full drying, took more time compared to the other two paper types having lower amounts of filling materail (i.e., 3–3.6%).

It is well known that ink absorption depends on the porosity, permeability, and capillarity of the paper. However, in the present study it was observed that the drying



Graph 1. Densitometric values during the drying period of inks.

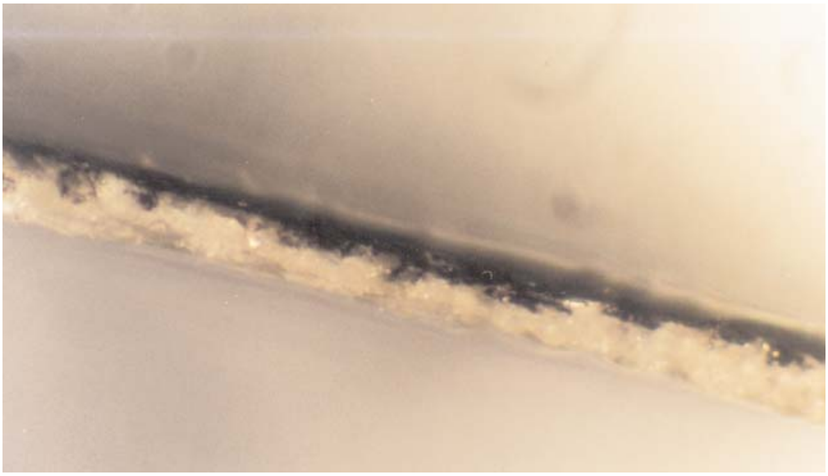


Figure 5. The paper-ink interface of the test print.

of ink took much more time although this white book paper had more porosity. The reason for this could be that the filling material in high proportion produced a resistance for the absorption of ink.

However, the densitometric value of the dark book paper has a higher value compared to the other two papers in the measurements carried out both during the printing measuring period.

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REFERENCES

1. W.H. Banks, "Inks, Plates, and Print Quality," Ninth International Conference of Printing Research Institutes, Rome, 1967.
2. M. B. Lyne and J. S. Aspler, "Ink-Paper Interactions in Printing," *Colloids and Surfaces in Reprographic Technology,* London, 1982.
3. Ronald E. Todd, *Printing Inks Formulation Principles, Manufacture, and Quality Control Testing Procedures.* Pira International, 2000.
4. Ingela Keskitalo, *The Penetration Profile of Water-Based Inks into Laboratory Sheets Made from Bleached Eycalypt Kraft Pulp.* Australian Pulp and Paper Institute, 2000.