Water Injection Trials with Ink Emulsions by Using a "Hele-Shaw cell"

Reinhard Tosch *, Ulf Lindqvist **, Jouko Virtanen **

ABSTRACT

Water injection tests were carried out with oily offset ink emulsions by using a "Hele-Shaw cell". To determine the water pick-up of the offset ink, the speed and the width of the finger-shaped aqueous phase injected into the oily ink emulsion were measured. The findings show, that there is reason to assume that the Fairbrother-Stubbs equation can be applied to describe the water penetration of offset inks.

* Free lance researcher, Frd. Rhode Strasse 5, D-7010 Leipzig, Germany
** Technical Research Centre of Finland (VTT), Graphic Arts Laboratory, Tekniikantie 4 B, SF-02150 Espoo, Finland

INTRODUCTION

The emulsification of a fountain solution in an offset ink is influenced considerably by the interfacial tension at the boundary between the ink and the aqueous phase, and by the viscosity of the ink. For a scientific prediction of this essential interaction in offset printing, it is important to depict the development of the normal modes of protuberant disturbances in a plane interface between the oily offset ink and the aqueous phase as well as their growth rate. It has been pointed out and verified experimentally /1/ that when two immiscible fluids with different viscosities are accelerated in a direction perpendicular to their interface, this plane surface becomes unstable in a certain speed range. The instability causes round bubbles (Saffman-Taylor fingers) of the less dense fluid penetrating the more dense fluid /2/ (cf. Figure 1).

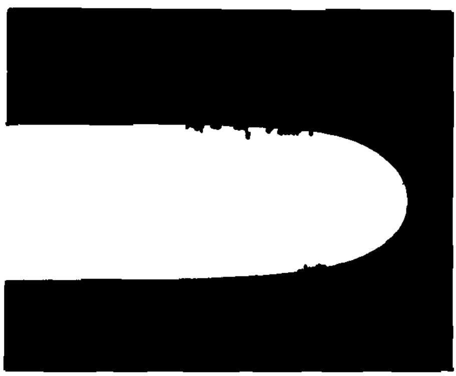

Figure 1. Penetration of a more dense fluid by a less dense fluid in result of "Saffman-Taylor fingers".

The concept of Saffman & Taylor /2/ is used here to characterize the penetration of water in offset inks as part of the interaction in the offset process. Special attention is paid to experimental data (width and speed) of the fingershaped water penetration in the ink phase and to their interpretation by the Fairbrother-Stubbs equation /3/.

TESTING TECHNIQUE

The penetration of water in oil can be studied by using the equipment introduced by Hele-Shaw /4/ - see Figure 2. The measuring gap of the Hele-Shaw cell is formed by two plates of glass separated by slim rubber lines. The oily ink to be tested is confined between these plates of glass.

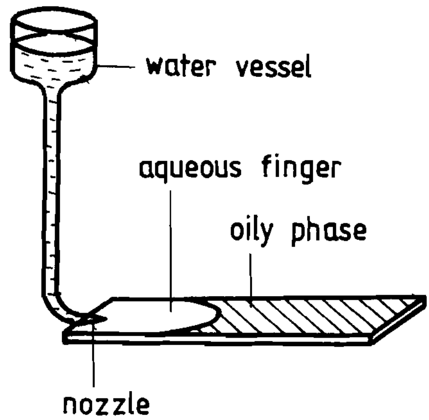

Figure 2 . A schematic diagram of the Hele-Shaw cell

The aqueous phase flows from a container down a tube through a nozzle into the Hele-Shaw cell. The driving pressure can be varied by changing the water level. The water begins to penetrate through the narrow nozzle in the form of a small bubble of liquid. The bubble swells into a finger shaped stream with the characteristic width and then passes down the measuring gap without any further change in the shape. This phenomenon is also known as "water tonguing", "coning" or "the viscous fingering effect" /5/. By measuring the time needed for the "finger" to travel a given distance, we obtain the penetration rate of the water injected into the oil-base ink. It can be shown that the interface is unstable, if the criterion

$$(\mu_2/k_2 - \mu_1/k_1) \; v < 0$$

is fulfilled /2/. In the equation, v denotes the rate of penetration, μ is the viscosity, and **k** is the permeability of the liquid phases. The indices refer to the tested liquids. The measuring gap of the Hele-Shaw apparatus must be long and slim enough to permit the finger-shaped water to penetrate the oily ink.

MATERIALS

Ordinary tap water was used as the water phase in the tests. The oily fluid was a conventional offset ink (magenta), containing two different types of oil - for the purpose of stabilizing the viscosity of the ink.

RESULTS

The results of the tests with water injections into the oil and into the mixtures of oil and ink are illustrated in Figure 3 showing the plot of the ratio λ

$$\lambda = \frac{\text{Width of the aqueous finger in the oil}}{\text{Width of the measuring gap}}$$

versus the velocity v of the aqueous finger penetrating the oily phase. An increase in the penetration rate of water in the oily phase corresponds here to a decrease of the ratio λ from the unity to 0.5. This result conforms,in principle, with the observations made by Saffman & Taylor on different oil-water systems.

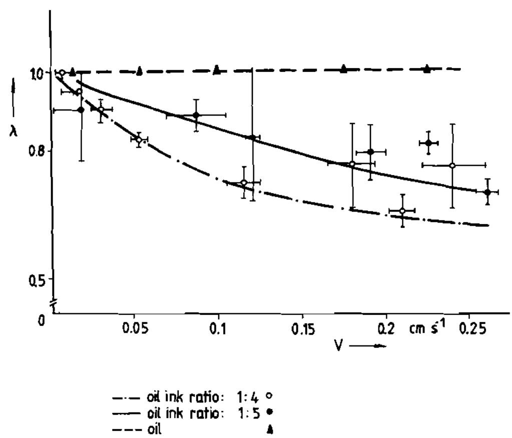

Figure 3. λ-v - plot of selected systems of tap water/oil and tap water/oily ink

A qualitative analysis reveals that the interfacial tension pulls the lagging oily ink emulsion film into the leading meniscus at a speed determined by the viscosity of the oily phase.This phenomenon is analogous to the behavior of a moving air bubble in a flowmeter capillary containing a liquid /3/.

To check this analogy in more detail, the test data from Figure 3 were plotted and analysed by a graph, showing the dependence of the ratio W= 4 (1 - λ) on the square root of the velocity v (s/cm) of the aqueous fingertip through the oily offset ink mixture (Figure 4).

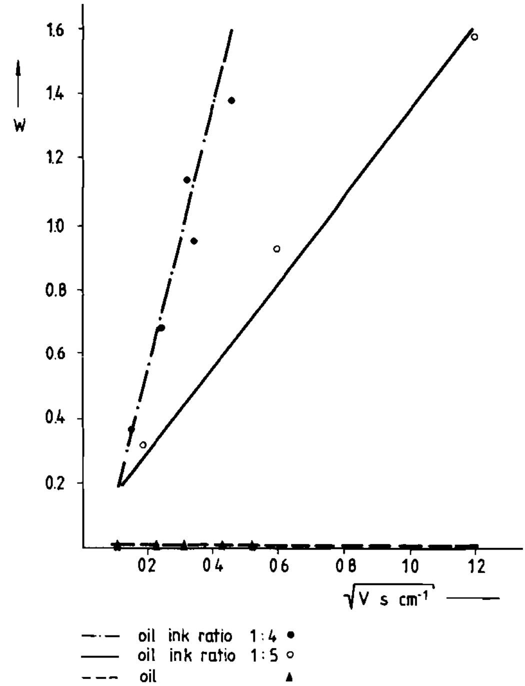

Figure 4: W - v - plot of selected mixtures of tap water and oil and oily ink

The plots show in each case a close approximation of straight lines. According to Fairbrother & Stubbs /3/, we have

$$\frac{W^2}{v} = \frac{\mu}{\sigma}$$

where μ is the viscosity of the oily phase and σ is the interfacial tension between the aqueous phase and the oily phase. From this equation follows that the ratio of **W^2/v** shows the rheological impact on the penetration of the aqueous phase in the oily phase. Figure 5 shows the ratio of **W^2**/v in the examined systems against the percentage of oil in the ink. The findings indicate that an increase in the oil content of the offset ink causes a decrease in the **W^2/v** ratio. When the oil is used as a viscous phase only, like here, the ratio approaches 0 in the speed range of the examined penetration of water.

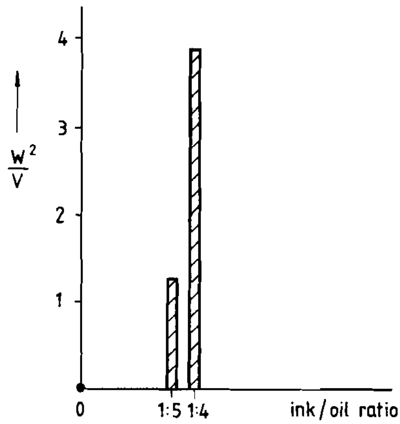

Figure 5. The influence of the percentage of oil in the ink on the W^2/v ratio

CONCLUSION

A Hele-Shaw cell device was used to characterize the nature of the emulsification of water in offset inks. With this device, water injection tests were made with oily emulsions of offset inks to get a visual picture of the mechanism in the penetration of the aqueous phase in the offset ink. These tests must be evaluated from a more methodical point of view. Further tests, including full-scale printing trials with various systems, are needed to show how the "viscous finger technique" is suitable for the evaluation of offset ink / fountain solution systems. However, the Fairbrother-Stubbs equation - if applicable to the complex interactions of the offset process - provides for a simplification in testing the compatibility of inks and fountain solutions.

REFERENCES

1. Lewis, D.J., The instability of liquid surfaces when accelerated in a direction perpendicular to their planes. II Proc. Roy. Soc. A 1068 (1950) p.81- 96.

2. Saffman, P.G., Taylor, G., The penetration of a fluid into a porous medium or Hele-Shaw cell containing a more viscous liquid. Proc. Roy. Soc. A 1242 (1958) p.312 - 329.

3. Fairbrother,F., Stubbs, A.E., Studies in Electroendosmosis. Part VI. The "Bubble-tube" method of measurement. J. Chem. Soc. (1935) Part 1, p.527 - 529 (1935).

4. Hele-Shaw, H.S.S., Trans. Instn. Nav. Archit., Lond. (1898) 40: p. 21.

5. Pascal, H., Pascal, F., Dynamics of interface shape in a porous medium for non-Newtonian fluids under gravitational and interfacial tension effects. J.of Colloid and Interface Science. 1 (1987): p. 91-97.