Modeling the deformation and flow of a half-tone dot during off-set printing

Douglas W. Bousfield
Paper Surface Science Program
Department of Chemical and Biological Engineering
University of Maine
Orono, ME 04469-5737

Presented at the 13th International Coating Science and Technology Symposium, September 10-13, 2006 in Denver, Colorado[1]

Offset printing involves the separation of printed and unprinted regions due to the hydrophilic or hydrophobic regions on a printing plate. This plate transfers these regions to a rubber blanket that presses these regions against paper. The regions are often broken up into small "dots" that are in the order of 50 μm. The increase in the dot size is important and is called "dot gain"; a good understanding of this issue is not clear in the literature [1,2]. Others have reported the influence of paper and blanket parameters on dot gain [3,4]. Current models are empirical. Also, the forces at the exit of the nip are critical in terms of understanding coating picking and blanket deposits.

A model is proposed for the printing nip that follows a half tone dot through the nip. The influence of the ink viscosity and surface tension, the dot physical dimensions, the roll radius and printing speed, the rubber roughness, ink setting, and compressibility are all taken into account. The fluid motion is described by a lubrication type analysis of the flow field. The pressure field within the dot is predicted as well as the net force and deformation. Figure 1 shows the general description of the model. The force-time relationship can be estimated knowing the roll radius and the operating speed, except the maximum force that the dot will see is not known.

---

[1] Unpublished.

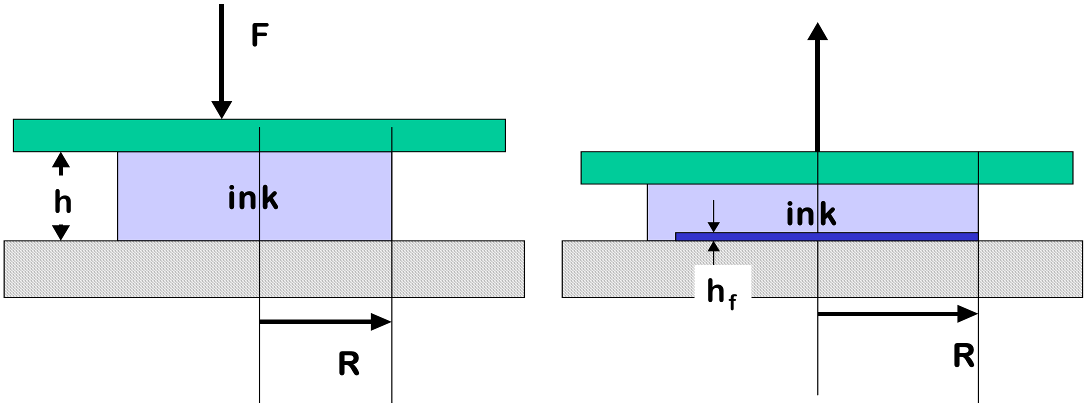

Figure 1. The pressing of an ink dot in a printing nip.

The fluid motion is described by the thin film equation given as

$$\frac{\partial P}{\partial r} = \frac{6\mu r U}{h^3}$$

where P is pressure, μ is viscosity, U is the current speed of compression, and h is the thickness of the ink film at any radial position. The thin film expression should be valid because the ink film thickness is often the order of one micron while the dot radius is on the order of 50 microns. The integration of pressure in the radial direction gives an expression that relates the velocity and the force. Other equations are used to describe the compression of the paper and rubber, and the absorption of fluid from the ink into the paper. The increase in the filtercake thickness h_f is described by

$$\frac{\partial h_f}{\partial t} = \frac{v_z \phi}{\phi_f (1-\phi)}$$

where v_z is the absorption velocity, and ϕ and ϕ_f are the solids volume fraction of the ink and the ink filtercake, respectively.

Figure 2 shows a typical pressure distribution within the dot it goes through a compression and expansion cycle. These results are for a web speed of 5m/s, an ink film thickness of 1.0 μm, a dot radius of 100 μm, and an ink viscosity of 0.1 Pas. The maximum force is adjusted to obtain a 10% increase in the dot radius; a typical value of dot gain seen in industry. The pressure at the center of the dot becomes large during compression as fluid flow from the center of the dot to the edges. As the boundaries open, a low pressure region is predicted that attempts to pull fluid back towards the center. This low pressure is much less than an absolute zero pressure and indicates that the ink will cavitate at the nip exit.

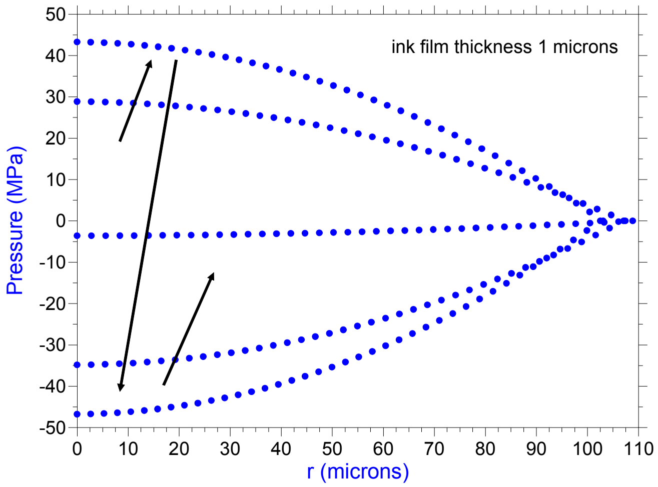

Figure 2. Pressure profile within the dot for parameters listed in text above.

Four coated papers, with different "setting" rates, were printed under similar conditions at a pilot press. The amount of dot gain, for various dot sizes, was characterized by microscopic images of the printed region. Setting rate is a general description of the rate that the papers absorb ink oils into the coating layer. This changes the parameters in the model that relates to the absorption rate into the paper during dot compression. The tack dynamics of these samples were characterized by the University of Maine "micro-tack" tester. This tester presses an inked cylinder against the paper and measures the maximum force to pull the probe away from the paper. The absorption rate parameter in the model can be adjusted based on this test.

Figure 3 shows the predictions of dot gain from the model compared to the dot gain seen in the pilot trial. One sample is not reported because the dots were elongated; this elongation must be from some speed mismatch during the printing trial. In general, the predictions are good. Smaller dot sizes show a tendency for a larger increase in dot size on a percentage basis: this comes from the resistance to flow in a thin layer.

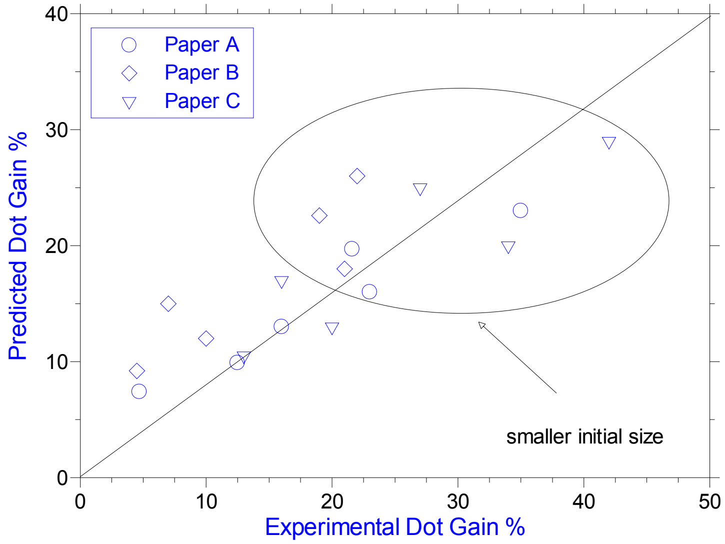

Figure 3. Comparison of predicted and measured dot gain for three of the four samples.

We thank the sponsors of the University of Maine Paper Surface Science Program for their support and discussions. Paper samples and printing trials were provided by J.M. Huber.

1. Chung, R. Y. and Ma, L.Y., “Press Performance Comparison between AM and FM Screening”, TAGA Proc., 321-328 (1997)
2. Chou, S.M. and Niemiro, T., “Dot Gain Characteristics of FM and AM Screens”, Proc. of 1998 Pan-Pacific and International Printing and Graphic Arts Conference, 207-210 (1998)
3. Lind J., J. MacPhee, “A Study of dot gain in sheetfed lithography as a function of paper grade”, Proc. 1990 Inter. Printing and Graphic Arts Conference, TAPPI Press, Atlanta, pp. 187-191 (1990).
4. Blom, B., Andrew, B., and Stroble, S., “Effect of Blanket Properties on Print Quality”, TAGA Proceeding, 39-56 (2001)