Experimental and Analytical Study of Dot Gain Between Elastic and Deformable Drums

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Abstract

During the printing process on liquid electrostatically printing (LEP), liquid ink is transferred from the ink tank to the media passing through a number of drums. First, the ink is transferred to the photoconductor drum, and then the inked image is transferred to the blanket drum by electrical forces, after drying the image on blanket drum it is transferred to the paper. Most of the printed images contain mid tone areas. These areas are composed of screened dots. When a dot is transferred from the photoconductor to the blanket, the dot is squeezed and as a result, the dot size increases. This phenomenon is called dot gain. The dot approximately expanded by 10% during the transfer between the photoconductor and blanket. In this work we present analytical model that simulate dot gain phenomena, a good agreement between analytical and experimental results are shown as well.

Introduction

Dot gain is well known phenomenon in offset lithography and some other forms of printing which causes printed material to look darker than intended. In practice, this means that an image that has not been adjusted to account for dot gain will appear too dark when it is printed.[1] On the offset printers ink is transferred from the printing plate to the blanket and from the blanket to the paper. Each time the dots get squeezed a little bit, increasing the physical diameter of the printed dot. Many efforts were done to compensate the dot gain phenomena in offset printers, either by correction the dots on the plate or compensate other optical effects during the printing process.[2-4] At indigo electroink process dot gain occurs mainly between photoconductor and blanket drums, due to high viscosity and thin layer of ink when it transfer to the different papers.

In both offset and Indigo digital processes dot gain can be considered as squeezing of fluid dots between two rotated drums. In our case drums are photoconductor (rigid) and blanket (deformable) as shown in Figure 1(a). Fluid flow between two rotated drums was studies widely in the literature; this problem is considered as elastohydrodynamic lubrication problems. Elastohydrodynamic lubrication is typically used when the pressure is high, the surfaces are elastically deformed and having relative velocities between the drums [5,6]. Unlike those works where the nip (drums contact) is fully flooded we have non continuous material between the two drums. For that matter we need to simulate the dot gain as a squeezing problem from point of view of axis tied to the dot itself and moving with it during the nip contact. In order to simplify this problem we consider the squeezing of the dots as typical squeezing dot between parallel plates approaching or receding from each another. This assumption can be taken into account due to the small size of the fluid dot (~100um) relative to nip contact size (~10mm). Moreover the dot thickness (~10um) is an order of magnitude smaller than the blanket deflection (~100um), therefore changes of fluid thickness will not affect the total forces between the two drums. These assumptions allow us to model the dot gain as squeezing dot between two parallel plates while the determined pressure between the two rotated drums can be used as an input for the applied force. Unlike typical squeezing dot problem dealt at literature [7] in our case at least one of the drums is deformable while dot is squeezed, this fact should be consider when we develop a model for this problem [8].

In this work, we will present a theoretical model that simulates the dot gain phenomena between two rotated drums (rigid and deformed drum). This model is based on elastohydrodynamic interactions that predict the dot size evolution as function of transfer parameters. The main transfer parameters which may strongly influence the dot squeezing in this model are: pressure between the two drums, ink viscosity and blanket surface properties. Understanding the effect of these parameters on dot size is an important step to achieve the accurate and desirable dot size on print. Finally we will show experimental and numerical results and comparison between them.

Analytical model

As shown in Figure 1, the photoconductor drum was assumed to be fully rigid. The blanket drum was considered as rigid drum that coated with low elastic deformable layer (soft layer) with elastic modulus of E~10MPa and thickness of L~50-200 um (Figure 1b). Figures 1b and 1c demonstrate the dot size before and during squeezing. During the squeezing process, the dot penetrates to blanket surface due to low elastic modulus of the blanket. The force on the upper plate will be taken from pressure profile defined by the pre-deflection of the two drums and can be measured separately and applied as input for our model.

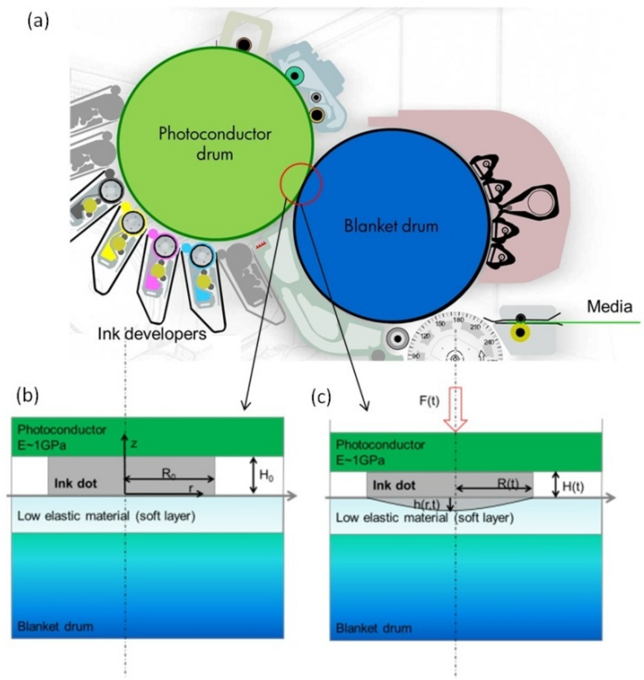

Figure 1: *(a) Schematic draw of Indigo process, (b) Schematic draw of a dot between two drums before squeezing (b) and during squeezing process (c).*

Typically, in order to include the elastic deformations in the elastohydrodynamic interaction, the Reynold's equation for the fluid is coupled to elastic modulation and then a numerical method is used for solving a nonlinear ordinary differential equation.[8] We assumed that the hydrodynamic solution would not change the total forces between the drums due to small changes in liquid drop thickness relative to large blanket deflection.[9]

Consider the drop of liquid of viscosity μ, between the rigid plate and elastic layer of low Young modulus *E* with thickness *L* as shown in Figures 1 (b-c). If the force *F(t)* exert on the upper plate (in *z* direction demonstrated) the drop spreads (squeeze) in the radial directions and the elastic layers deforms approximately in the *z* directions. The force *F(t)* increases from zero, reaches maximum and decreases to zero. The final deformation of the soft layer of the bottom plate at the end of the process achieved when *F*=0 at end or when *H*=0 which mean the distance between the plates is zero and drop warped by the soft layer.

The lubrication equation for the liquid is

$$\frac{\partial P}{\partial z} = \mu \frac{\partial^2 u}{\partial z^2}$$

Where *P* is a pressure and *u* is a radial component of velocity. Combining Coyle's assumption [10] which assumes that local elastic deformation is propositional to local pressure of the liquid into the lubrication equation with assumption mass conversation and boundary conditions we can solve this nonlinear ordinary differential equation (ODE).

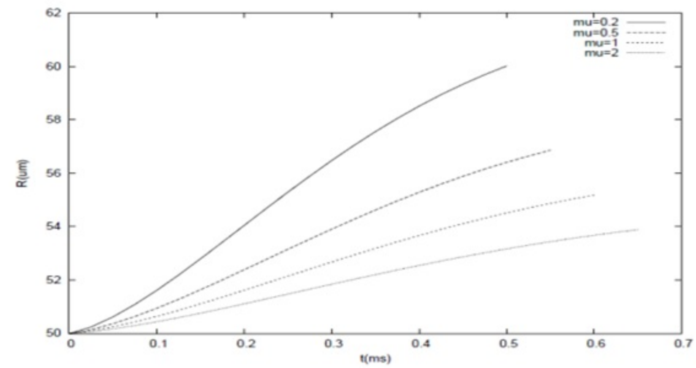

Figure 2: *Dot diameter as function of time for different ink viscosities. Blanket elastic modulus (soft layer) E=2MPa; soft layer thickness) L=80um; initial dot height H_0=5um; initial dot radius R0=50um.*

Numerical and experimental Results

The simulation results showed that the dot size is mainly affected by the ink viscosity and the elasticity of blanket (Figures 2 and 3). As the ink viscosity decreased the dot size is increased. Moreover, dot size increased with blanket elasticity. A good correlation was found between the experimental results and the theoretical model (red stars, Figure 3). It was shown that the dot is generally expanded by ~10% during the transfer between the photoconductor and blanket at standard conditions.

Figure 4 present the dot diameter as function of the transfer pressure for different blankets. Our experimental results showed that for all blankets at low temperature, the dots start to smear at lower pressure due to ink cohesion. For blanket A and blanket B, dot size increased with the transfer pressure due to dot squeezing at specific pressure, the dots start to smear (Figure 4, small images). However, for blanket C, pressure has negligible influence on dot size. These differences can be explained due to blankets soft layer properties.

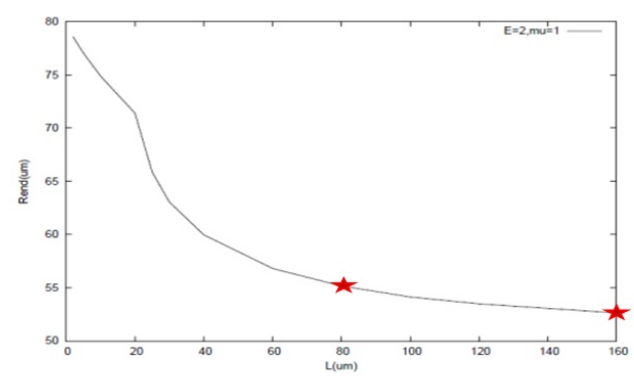

Figure 3: *Final dot diameter as function of soft layer thickness; red stars represent typical experimental results. Initial conditions: ink viscosity μ=1 Pas; blanket elastic modulus (soft layer) E=2MPa; initial dot height H_0=5um; initial dot radius R_0=50um.*

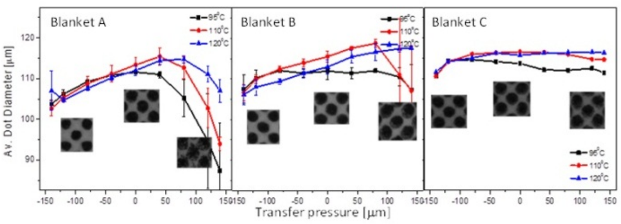

***Figure 4:** Dot diameter as function of temperature as the transfer pressure between photoconductor and blanket drums. Three different blankets A, B and C. Dot shape is seen in inset images.*

Summary

In this work, we present a theoretical and experimental results describe the dot gain phenomena between two rotated drums (rigid and deformed drum). This model is based on elastohydrodynamic interactions that predict the dot size evolution as function of transfer parameters. We found that as the ink viscosity decreased the dot size is increased. Moreover, dot size increased with blanket elasticity. A good correlation was found between the experimental results and the theoretical model. It was shown that the dot is generally expanded by ~10% during the transfer between the photoconductor and blanket at standard conditions.

Acknowledgments: thanks for Naseem Yakov, Eric G Nelson and Bruce Jackson from HP, for their good discussions and help.

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