Development of a testing method for show-through/bleed-through of writing papers.

The current popularity of roller ball pens using liquid and gel inks allows the penetration of inks through the surface and into the sheet which leads to the ink penetrating through pores in the sheet to the other side (bleed-through) or the writing becoming visible on the unwritten side of the sheet (show-through). Both these problems can be limited in paper with producing higher sheet density, lower porosity, lower surface roughness, addition of surface or internal sizing. Show-through can also be limited at a given sheet basis weight by having a high scattering filler content in the sheet.

This project aims to develop a test where the volume and rate of application of non-viscous liquid ink is applied to paper surfaces in a controlled and reproducible fashion. The printed samples are measured on their unprinted undersides for color changes attributable to the combination of bleed-through and show-through. Quantification of the combined show-through and bleed-through effects using a reproducible controlled ink delivery systems removes the subjectivity and arbitrariness of visual ranking of hand-written samples using various types of pens and inks.

Bristow wheel printing – This is an adaptation of an ASTM method where 1 inch wide samples of the notebook papers cut along the CD are mounted onto a rotating wheel set to have a linear speed of 4.5 meters/min in keeping with standard fast handwriting speed used in in other documented studies[1]. Parker Washable Blue Quink™ fountain pen ink is measured by pipette to 75 microliters volume and placed into the slotted die (slot is 1 x 15 mm) applicator suspended above the wheel. A swath of ink 15 mm wide becomes applied from the applicator to the sample once placed in contact at the start of the moving sample strip. The printed surface (which is the labelled side of each paper pad) then passes 2 250 Watt IR lamps to facilitate fast

[1] **Hollerbach, J.M. (1981). An oscillation theory of handwriting. *Biological Cybernetics*, *39*, 139-156.**

drying of the surface and removal of the sample. 6 sample strips were printed from each sample pad

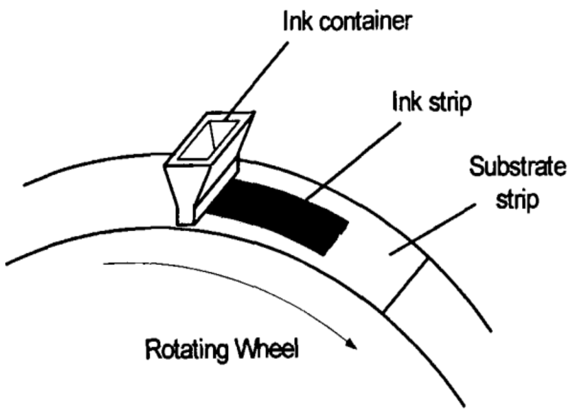

Figure 1. The Bristow wheel concept.

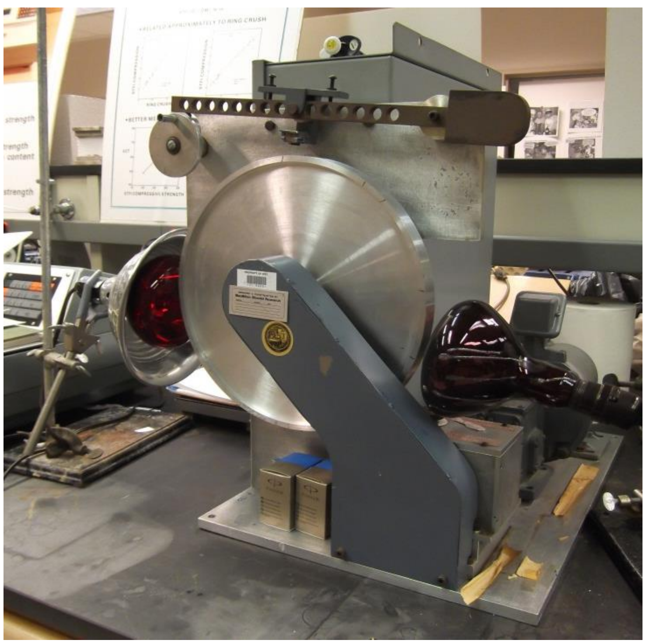

Figure 2. Bristow wheel with IR lamp driers.

Bleed-through/show-through measurement - The unlabeled side of the unprinted paper pads were measured for CIE Lab* coordinates L_u* a_u* b_u*, using a Technidyne Brightimeter S5 having a 0.5 inch measuring port. The undersides of printed samples were measured in 3 different spots along the length of each strip. Optical measurements are all made along the MD in this Tappi method. The average of 3 Lab* readings were made for 5 strips for each sample and an average for the printed underside calculated: L_p* a_p* b_p*. The change in color and shade of the underside attributable to printing of the labelled side is called delta E thus:

$$\Delta E = \sqrt{\{(L_u^* - L_p^*)^2 + (a_u^* - a_p^*)^2 + (b_u^* - b_p^*)^2\}}$$

A Bristow wheel was used to apply swaths of Parker Washable Blue Quink fountain pen ink to a sample set of selected notebook and writing tablet papers. The concern is to determine a series of physical properties and their values that effect the degree of show-through and bleed-through that occur with the use of popular low viscosity ink pens. Paper is manufactured to satisfy specifications for physical properties such as roughness, opacity etc. which may not reflect the interaction of ink with paper. The objective here is to determine which properties are critical for ink on paper performance so that the criteria may be specified for the manufacturer to meet.

Intuitively, porous, high bulk, high roughness papers are expected to be highly absorbent and unsuitable for writing or printing. However, the penetration of into and through the sheet is governed by capillary action which is influenced more by the presence of sizing agents and surface energy.

Figure 3. Top inked side of a selection of notebook and tablet writing papers inked using the Bristow wheel as specified. Note there is also a variation in ink density and mottle.

Figure 4. Underside of the inked strips shown in Figure 3 displaying varying degrees of show-through.

This project finds that for the selected sample set of writing papers, the liquid absorption properties play a principal prevailing role in determining the level of acceptable ink-paper performance. Water drop contact angle and contact angle change rate are introduced.

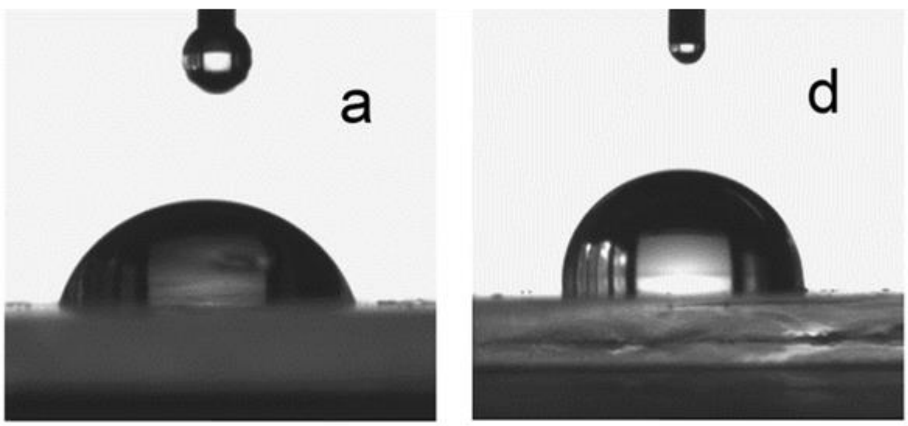

Figure 5. Low (a) and a high (d) contact angle water droplets. **The surface in a) is hydrophilic and in d) it is hydrophobic.**

Water drop contact angle is known to relate to “ruling quality” such that if the angle the sides of the drop make with surface are between 110 and 90 degrees, sharp lines are formed since the ink will stay where applied. Angles greater than 110 will cause applied lines of ink to break up, contact angle of less than 90 will lead to “feathering” or lateral spreading of the lines. The change in water drop angle with time is also known to be related to feathering propensity. Delivery of a 4 microliter drop, video recording of the water drop absorption and measurement is facilitated by a Fibro PG-3 instrument connected to an analyzing computer.

Another test adopted from STFI studies[2] of ink-jet paper characterization is liquid water absorption (Cobb test) where a sample is exposed to a pool of water placed on its surface for 30 seconds and the absorbed water is measured as a weight difference of the blotted sample after water exposure.

Thus, the Hercules size test (HST), water drop contact angle, contact angle change rate, and Cobb all test the paper for presence of sizing and in combination show a good correlation with bleed-through and show-through as measured by the change in optical CIE Lab* measured on the underside of inked samples. A multiple regression model of the form:

$$\Delta E = a_1 x_1 + a_2 x_2 + \ldots + a_n x_n + b$$

is used to combine the values from these liquid absorption tests to produce the best available predictor for delta E determined from the ink application test. The Regression function in the Excel Data Analysis Tools package provides a convenient means of doing this. Significance of the fit of the model variables is assessed by an overall high correlation coefficient, low p values for the x_i variable coefficients a_i and a low calculated Significance F value. In this sample set of notebook and writing tablet papers the best regression equation was determined to be:

$$\Delta E = -0.0312 \times (HST) + 0.170 \times (\text{contact angle}) + 2.60 \times (\text{angle rate}) + 7.86 \times (Cobb30/bw) - 10.3$$

with an average error of ± 1.91 points. The Cobb values are divided by the sample basis weight ***bw*** in g/m^2.

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[2] Erik Blohm, STFI reports on Papers for High Speed Ink Jet Printing, CW 248 and 119, December 2204 and 2005/

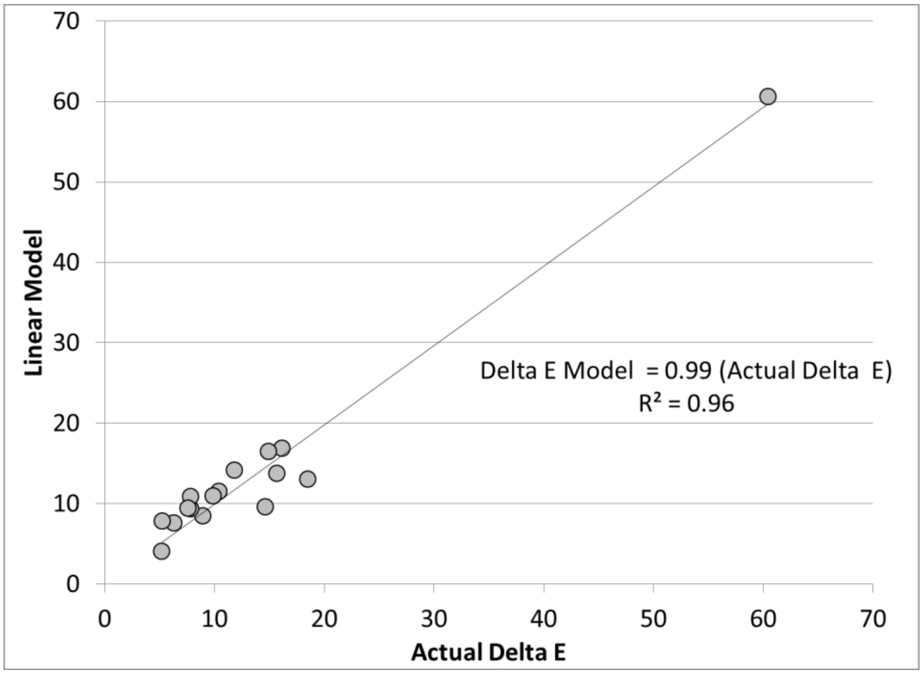

Figure 6. Comparison between the linear model and actual delta E values for the notebook and tablet writing paper sample set shown in Figures 3 and 4.

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