Study of ink mileage and print through
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Summary:

This report contains a study of ink mileage, show through and other mechanisms that are important in the study of substrate printability. These mechanisms have an impact on how ink will react on paper. To develop a substrate that provides good ink mileage and less show through requires a closer study of substrate characteristics.

Substrates with different characteristics have been tested by a technique developed for this project called modified ink mileage. Ink mileage is a method to determine how much ink that is required for a certain target density. Further tests on the same substrates have been done including print through and surface roughness measurements.
Contents

Introduction 6

Background 6

Purpose 6

Goal 6

Method 6

Limitations 6

Implementation 1 7

Ink mileage 1:2 7

Ink amount 1:2:1 8

Density 1:2:2 8

Measuring instrument 1 / Prübau 1:3 8

Construction 1:3:1 8

Ink distribution 1:3:2 9

Attaching the aluminium forme 1:3:3 9

Inking-up period 1:3:4 9

Carrier 1:3:5 9

Size of printing samples 1:3:6 9

Printing procedure 1:3:7 10

Print through 1:4 10

Opacity 1:4:1 10

Measuring instrument 2 / Opacity meter 1:5 10

Values of reflection 1:5:1 11

Equations for Opacity and Print through 1:5:2 11

Measurements 1:5:3 11

Calibration 1:5:3:1 11

Roughness 1:6 12

Measuring instrument 3 / L&W PPS Roughness Tester 1:7 12

Instrument 1:7:1 12

Importance of clean instrument 1:7:2 13

Calibration 1:7:3 13

Equation 1:7:4 13

How reliable are laboratory studies? 1:8 13

How absorption impact on tests 1:9 13-14
Laboratory studies 2  
Substrates 2:2  
  Coating 2:2:1  
  Calendered paper 2:2:2  
  Pore structure 2:2:3  
Technique development 2:3  
  Bench marking/ink mileage 2:3:1  
  Temperature/speed/pressure 2:3:2  
  Best technique/modified ink mileage 2:3:3  
  Color distribution 2:3:4  
Modified ink mileage test 2:4  
  Density measurements 2:4:1  
  Calculation 2:4:2  
  Log 2:4:3  
Print through measurements 2:5  
Roughness measurements 2:6  
Pore structure 2:7  
Deltack measurements 2:8  
Further tests/group two & three 2:9

Conclusions 20-21

Acknowledgements 22

References 23

Appendix A  
(1) Prüfbau

Appendix B  
(2) Opacity measurements

Appendix C  
(3) L&W PPS Tester / section through a measuring head

Appendix D  
(4) Ink mileage/GROUP ONE

Appendix E  
(5) Print through/GROUP ONE
Appendix F
   Roughness & Pore structure/GROUP ONE

Appendix G
   Ink setting curves/GROUP ONE

Appendix H
   Results/GROUP TWO side 1, 2 and 3

Appendix I
   Ink mileage/GROUP THREE

Appendix J
   Weight measurements on aluminium forme

Appendix K
   Time plan

Appendix L
   Typical curves on a printability analysis
Introduction

This report represents a 10 point degree project in Graphic Technology. The project has been performed in cooperation with paper company International Paper (Cincinnati, OH) and a chemical company, Dupont. In appendix K there is a time plan for this project.

Background

There are many mechanisms that interact with each other to determine a substrate printability. How much will the ink penetrate if you use more or less coating? How much ink holdout will you get if you use more or less filler? How smooth does the substrate have to be to give good ink mileage? All have something to do with each other, in order to produce a coating that makes your paper better than those of the competitors you have to start looking at these things on macro scales. In a big scale you can tell that one or another paper is going to give you higher ink holdout. But when you start to look at paper in a very narrow range you can not tell by visualizing if it gives you good or bad ink mileage. There can be very big differences in percentage when you look closer on papers in a narrow range.

Purpose

The purpose of this project is further understanding of how to manufacture substrates with good ink mileage, but still with good printability.

Goal

The goal is to develop lightweight coated (LWC) products that provide significantly more ink mileage or less ink show through than current competitors. This will lead to a cheaper substrate which provides additive value for International Papers customers.

Method

Create a reliable benchmarking technique for ink mileage/ink show through determination. With an instrument called Prüfbau, create tests using different substrates and amount of ink. Together with International Paper and Dupont’s expertise in Mercury porosimetry, try to understand the role of pore volume/pore size as a variable on ink mileage/show through.

Finally determine other mechanisms, such as roughness, that have an impact on ink mileage.

Limitations

Limitations that were made for this project were the number of paper samples that were supplied. Further test will be made on other substrates later.
Implementation 1

In a laboratory study of paper printability, it is common practice to determine the print density of a series of prints bearing different quantities of ink and then evaluate the ink requirement for specified print density (N. Pauler, 2002). This project is an analysis based on this kind of laboratory study. By using available instruments, find a reliable benchmarking technique for ink mileage.

A printability evaluation includes not only a determination of the print density but also of print through in relation to the ink applied (see appendix L). Also the surface smoothness has an impact on how ink acts on different substrates. Therefore these mechanisms are analyzed for this project.

This report is a part of one continuing project. The part that this report contains is a developing process and the first analyzed tests.

Ink mileage

There are different mechanisms that try to explain the interaction between paper and ink. One is ink mileage, which is a way of determining the ink requirement at a certain density value. In figure 1 you can see one typical curve on print density as a function of ink requirement. Differences in ink requirement at a constant Y-value are indicative of differences in the degree of interaction between ink and substrate.

![Figure 1: Print density as a function of ink requirement. A coated paper may give a higher Print Density at high ink quantities than a paper with less or no coating.](image)

Fig. 1 Print density as a function of ink requirement. A coated paper may give a higher Print Density at high ink quantities than a paper with less or no coating.
Ink amount 1:2:1
The ink requirement at a certain print density is determined by measuring the weight difference of the aluminum forme (which you use while testing) before and after running through a printing unit. Later in this report you can read about the procedure making these kind of ink requirement tests.

You get the ink requirement for a certain density by taking the ink amount divided by the printed area. Which results in a ink requirement by g/m².

Density 1:2:2
Print density: The colour depth (optical density) of a printed image.

The print density D is calculated according to the expression:

\[ D = \log\left(\frac{R_\text{p}}{R_\text{p}}\right) \]

Where \( R_\text{p} \) is the reflectivity of the paper and \( R_\text{p} \) the reflectance factor of the print (N.Pauler, 2002).

To get the print density you use a Densitometer.

Measuring instrument 1/ Prüfbau 1:3
There are different devices made to simulate press-printing variables for the assessment of papers and inks under controlled conditions. Those in common use are IGT print tester, Proof press, Prüfbau print tester, RNA print tester and Vandercook proof press. (www.indiapapermarket.com).

For this project Multipurpose Printability Tester/Prüfbau has been used to simulate the printing process in order to analyze ink mileage (see appendix A).

Construction 1:3:1
The inking unit consists of two temperature-controlled steel distributing rollers and one removable inking roller made of synthetic material/rubber. This inking roller has four separate sections making it possible to test either of four different inks, or amounts of ink, side by side. (Manual of Prüfbau)

As Printing form, which get the ink transferred by the inking roller, you can use both aluminium or blanket covered rolls. Aluminium print forme were used for this study for several reasons. First, the amount of ink transferred to the paper is very small and must be weighted with a precision of 0.0008 grams to maintain accuracy and reproducability. Blanket covered rolls were found to be very interactive with ink and paper which made them difficult to work with as a reliable test system. In addition solvent retention in the blanket can dramatically change the weight of the forme. Evaporation time of 30 minutes or more is needed for solvent to completely evaporate from the interior of the blanket.
Ink distribution 1:3:2
Ink distribution is measured most conveniently with a Prüfbau pipette. During this kind of test very small ink amounts are applied. Therefore, the weight of ink applied has been measured using a scale. »Ink should be applied evenly and over the whole width of section to aid distribution and prevent loss of ink through flying off during the first few revolutions of the roller« (Prüfbau manual).

Attaching the aluminium forme 1:3:3
The aluminum form can be attached on the idler arms and printing unit (see appendix A) by using three fingers. The form is held in place by permanent magnets. It can also be attached by using tongs that are provided with the instrument. Using the tong reduces the impact on the test results.

Inking-up period 1:3:4
The inking-up period combines distributing time and forme inking time. It is suggested that both times be kept constant, using a stop watch. The distributing time of ink on inking rollers must be kept short to prevent changes in ink quality resulting from evaporation or oxidation. Concerning almost all inks, complete distribution is achieved in 30 seconds. This is reduced to 15 seconds with heatset inks. (Prüfbau manual)

After distributing time is over you slowly lower the aluminium forme with the idler arm on to the distribution roller. Inking-up time is kept the same as distribution time.

Carrier 1:3:5
For this project, the carrier was a blue offset blanket. This kind of carriers is a standard for quality tests. Carriers are available for printing samples with thicknesses from 0.05 to 2 mm. Further standard carriers are available: 0.03-0.2 / 0.2-0.35 / 0.3-0.45 / 0.4-0.55 mm. Which one you choose to use depends on how thick the paper is that you are testing.

Size of printing samples 1:3:6
»The size of the printing samples should be 230(±2)x47(±0,5) mm«
If the strips are cut wider, they can stop the carrier from being transported through the track. On too narrow strips the print may not be centered (Prüfbau manual). For this project strips were pre-cut using a special designed instrument on which the recommended size already is adjusted. Strips are cut against fiber direction.

To attach the strips on the carrier you insert the paper in a metal clip at the end of the carrier. Then you stretch the strip over the carrier attaching the end of the strip with a piece of tape. To keep the surface free from fingerprints under this procedure gloves are used.
Printing procedure 1:3:7
When everything is prepared with paper on carrier and ink is distributed on the aluminium form it is time for the print. Print pressure and interval time are set before printing. Aluminium forme is removed from its idler arm on to the second printing unit.
You insert the sample carrier into the carrier track, to the left of first printing unit. Then start both printing units and then push the carrier and it automatically passes through both printing units. You can see a printed strip in Appendix A.

Print through 1:4
A Printability evaluation includes not only a determination of the print density but also of print through in relation to the quantity of ink applied (N. Pauler, 2002). Print through is total value of ink penetration and show through. Values are determined by measuring the substrates opacity.

Opacity 1:4:1
The papers optical characteristics such as reflectivity, brightness, whiteness, opacity and color is significant in determining a substrates printability.

»Opacity is an indication of the transparency of a sheet of paper measured in percentage. Good opacity=Opaque« (Hallberg, 2001)
A satisfactory degree of opacity is required in printing to avoid show through from the opposite side of the printed sheet. A degree of whiteness is also desirable as this affects the contrast of the image and the overall print quality. (www.naa.gov.au)
Opacity is a comparison of the percentage of light reflected by a sheet of paper with black backing compared to the light reflected with a white backing. (Cain, 2002, s 1) To measure the Opacity and total Print through of a paper you use a opacity meter which measures the reflectivity. »The optical characteristics is a result of two processes that occur when light interacts with the paper. Light absorption and light scattering«. (Fellers & Norman, 1998, s26-27)

Measuring instrument 2 / opacity meter 1:5
To get the opacity, print through, show through and ink penetration four reflection measurements are required. These measurements can be done using different equipments. Equipments that can be used are for example Datacolors Elrepho 2000 and Technidyne TB1C that both use ISO 2469 demands for measurements. (Fellers & Norman, 1998, s 361) In this case a opacity meter called Technidyne Model 425 has been used.

ISO 2469 has established that measurements should be done:
1. with diffuse lights
2. with C as source of light
3. according to CIE 1931 standard observer. (standard for color measurements)
4. without gloss component
Values of reflection 1:5:1
Values that are used making equations on opacity, print through, show through and ink penetration are, R₀, Rₐ, Rₗ and Rₓ. (See appendix B)

Rₐ »Reflectivity of the paper«, Reflectance of infinite thickness of paper.
Rₗ Reflectance of reverse side print backed by infinite thickness of paper
Rₓ Reflectance of ink film through a single sheet of paper, backed by infinite thickness of paper
R₀ Reflectance of a black surface through a single sheet backed by infinite thickness of paper

Equations for Opacity and Print through 1:5:2
By using the opacity meter you can get all reflectance values that are described above. With those values, you are able to make equations on opacity and print through.

In order to describe reflections of light of thin layers Kubelk & Munk deduced equations. The current equation can only be used with measurements made with diffuse light. Therefore opacity measurments are still made with diffuse lights. (Fellers & Norman, 1998, s 354)

The following equations are used:
Opacity=100*R₀/Rₐ
Total Print through= log(Rₐ/Rₗ)
Total Print through= Show through + ink penetration

Show through= log(Rₐ/Rₓ),
Ink penetration= log(Rₓ/Rₗ)

When these values are tested the same substrate must be used on all four values.

Measurements 1:5:3
In an opacity meter the reflection factor is measured, i.e the diffuse light that is reflected from the paper. (Fellers & Norman, 1998, s 362)

Calibration 1:5:3:1
Calibration: make adjustments for a process from values that are established. (Hallberg, 2001)

It is very important that these kind of instruments are calibrated. The opacity meter that was used in this project is calibrated every day in use. Calibration is made by reading a reference specially made for this instrument. The value you get have a tolerance on +/- 0,3.

The manufacturer is responsible for the spectral calibration, i.e that measurements are made by given wavelengths.

User is responsible for the photometric calibration, i.e make adjustments so the instrument is correct.
When calibration is done you choose a reflectance measurement and then insert the paper within a marked area. On the instrument you press on a test button. After inserting paper and pushing test button sample must not move around. Otherwise the black and white bodies will land on different places on the sample affecting the result.

**Roughness 1:6**

The characteristics of high and low topographical areas of paper deviating from the plane of its surface, the roughness being of visual to microscopic proportion. ([www.indiapapermarket.com](http://www.indiapapermarket.com))

To explain the surface roughness the most common method in use is based on leakage of air measurements. (Fellers & Norman, 1998, s 382)

There are different instruments to measure surface roughness. For this project Lorentzen&Wettre roughness tester has been used. It works in accordance with the PPS (Parker Print Surface) method.

**Measuring instrument 3/L&W PPS roughness tester 1:7**

**Instrument 1:7:1**

When measuring roughness, the paper sample is fixed with a specific clamp pressure between the measuring head and the backing (See appendix C, L&W PPS Tester). The surface of the measuring head (see appendix C, section through a measuring land) consists of two rings:

- a circular measuring land
- an inner and outer circular guard land which provide an airtight seal against the paper

Between these three lands there are two air slots through which compressed air passes. Compressed air is applied through the inner air slot, passes between the measuring land and the paper, back through the outer air slot and out into the atmosphere. (L&W PPS Tester, operating instructions)

There is a Photocell (see appendix C) that starts the measurement automatically as soon as it senses the paper. The paper top side is measured.

Before any measurements are made you have to tell the machine how many measurements you need, and it calculates a mean value.

Select the clamp pressure (0.5/1/2 MPa) and backing, depending on the grade to be tested.
**Importance of clean instrument**

Measuring the roughness of paper to a thousandth of a millimeter is a complicated task. Many factors affect the results. The precision measuring head is especially sensitive to dirt and damage. To make sure there is no dirt, you can clean the measuring head by using an air nozzle supplied with the instrument.

**Calibration**

The instruments used to this project are calibrated everyday. For the opacity meter, calibration is made with two check films. With zero check film a difference < 0.6 is OK and with second check film is a difference +/- 0.15 OK.

**Equation**

The connection between measured torrent of air and the surface physical structure has been analyzed by Parker who deduced an equation:

\[ Q = G^3 \cdot \Delta P \]

G = distance between two parallel boards
P = pressure

**How reliable are laboratory studies?**

A laboratory test simulates a real test, but there are many factors that affect the printing procedure. The ink mileage tests are very sensitive because the ink amounts is as small as 0.0008 gram. Temperature can change in the lab and have an impact on the test. Time delays caused during weight measurements can also change the ink quality. Finger prints on aluminium on form and paper can have an impact on final print.

**How Absorption impact on tests**

Printability: The ability of paper to give the most faithful reproduction of the original image at the maximum efficiency (www.indiapapermark et.com).

Every substrate has different abilities and when ink sets to paper, ink absorption mechanisms has a big impact on ink mileage and ink penetration. Ink on paper is a competition between spreading and capillary absorption. Spreading (or wetting) is the predominant mechanism in uncoated papers. Capillary absorption is the dominant mechanism for coated grades see figure 2 and 3 below. Spreading is essentially instantaneous and affected by paper surface area, surface energy, contact angles, etc. Capillary absorption is time dependent and affected by the number and size of pores, smaller is faster.
Fig. 2 Spreading is the predominant mechanism in uncoated paper.

Fig. 3 Capillary absorption is the dominant mechanism for coated grades.

Elements of the ink can either penetrate into the paper or stay on the surface depending on how big the pore size is. With their capillary force they drag the different elements into different depths of the substrates, as shown in figure 4.

Fig. 4 How pores trap ink components
Laboratory studies 2

Substrates 2:2
Three groups of paper, with different characteristics, were tested:

• Group one contains 5 papers all with different grades in coating. Paper that will be referred to as #3 gloss (reference paper Coated, grade 3) #4 gloss (LWC grade 4), #5 gloss (LWC grade 5), #5 dull (LWC grade 5) and SC (super calendered)

• Group two contains 16 papers which Dupont delivered for this project, with different pore structures.

• Group three contains 13 papers with different bulk characters.

Coating 2:2:1
To make the paper printability better you can use a coating. A layer of clay, binder and starch (precoating) and latex (top coating) covers the surface (Hallberg, 2001).

Coating and its characteristic are graded depending of how glossy, smooth and white the paper gets with its coating. There are five categories of coated paper from the brightest (No.1) to the dullest (No.5)

Calendered paper 2:2:2
Machine calender: A device for smoothing the surface of the paper to improve the finish and reduce the printing roughness of the paper.
Super calender: A set of alternating polished steel and composition rolls resting one on the other in a vertical bank, capable of producing a more uniform smoothness and gloss than a machine; calender, thus used to produce a smoother, glossier and denser sheet; usually off-machine. (www.indiapapermarket.com).

Pore structure 2:2:3
Depending on the pore size and volume ink penetrates more or less in to the surface. Therefor the pore structure has an affect on the printability of the paper.
**Technique development 2:3**

**Bench marking/ink mileage 2:3:1**
In the first part of the project tests were made trying to find a reliable technique for determination of ink mileage, how much ink a substrate needs for a certain density. This by using test papers of group one. All ink mileage tests made are on the Prüfbau.

**Temperature/speed/pressure 2:3:2**
Every test made on the prüfbau has been done in a laboratory environment where temperature and humidity is kept on 72 F / 54%. Speed and pressure has been the same for all tests:
- Speed: 2 m/s
- Pressure: 1200 N

**Best technique/modified ink mileage 2:3:3**
The technique that is developed and gave most reliable data is a method called Modified ink mileage. By modified ink mileage you make an interpolation of earlier curves obtained. You look closer on the density span that you are interested in. In this case the target was 1.7 which is a standard for black ink, see figure 4. Black proofing and mottling ink were used.

**Curve interpolation**

![Curve interpolation diagram]

*Fig. 4 By interpolation you look closer on earlier curves obtained.*
**Color distribution 2:3:4**
A piece of rubber and a scale with an accuracy of one thousandth are used to get the exact amount of ink applied. The rubber piece is put on the scale which you set to zero and then apply the ink amount that you want to be applied on the inking cylinder. How much ink that is required for density target 1.7 must be tested for each paper. Ink amounts that have been used for substrates for this project is around 0.18-0.2 gram.

**Modified ink mileage test 2:4**
By not re-inking the aluminium forme instead put it back on same distribution section between each print you get a span in density that is in a narrow range.

To find out exact ink amount that is required for a certain density you have to take the weight of ink amount on aluminium forme before and after printing. (see appendix J). Then by substract the two values you get from the weight before and after print you get ink amount applied on paper.

This is how you do the modified ink mileage test:

1. Take the weight of how much ink you want to apply.
2. Apply ink on inking roll.
3. Take the weight of ink remaining to know how much you applied.
4. Let ink run 30 seconds on inking roll then 30 seconds on aluminium forme.
5. Take weight of aluminium forme with ink on.
6. Run a print.
7. Take weight of aluminium forme after print.
8. Re-ink the aluminium forme in 30 seconds on same section of the inking roll as first used.

Continue the same way from number five until four strips are printed. By doing tests like this you get four strips with density values that are in a narrow range.

What can be an issue in this case is the time delays that you get by taking the weight between each print. That can change the ink quality.

**Density measurements 2:4:1**
If you do density measurement just after printing you will get a density that is much higher than it should be. Ink with its solvents continues to penetrate into the substrate after print. Because of that, all prints that were made got to air dry over night before density measurements were made.

Measurements were made with a densitometer. You get the ink films density by first using an unprinted area of the test paper as a reference and then measure ink film, print – paper (D-).
Calculation 2:4:2
When you have data on ink amount of each strip you make a calculation on how much ink that is required for total area. Total ink amount that is required for each strip in gram divided by the printed area (200x40 mm in square meter 0,008m²). You get a value in g/m².

The data you got, density and ink amount, for each strip is plotted by using program Excel (see appendix D, ink mileage)

Log 2:4:3
Every test series was fitted to a log function. This in order to verify the accuracy (see appendix D, log). This is a function you can use to see if your four points that you got fits with each other. R² have to be > 0.9, if it is not, the data can not be trusted and the test has to be repeated.

You can also use this function to calculate how much ink is required for your target 1,7.

For example if you use the log from appendix D:
Y=1,2064 Ln(x) + 1,7977

The ink amount required you get by putting
Y=1,7
Ln(x)= (1,7 - 1,7977)/1,2064= -0,0809

x = ca 0,92 g/m² (total ink amount that is required for density 1,7)

Print through measurements 2:5
After every print were made on #3 gloss, #4 gloss, #5 gloss, #5 dull and SC four strips for each paper. Print through measurements were made on them by using the opacity meter. Two values on each strip were taken to get a mean value. Every value for R∞, R₀, R_q and R_X that you need for Print through calculations were all put in a data table in Excel and plots of opacity versus Print through, show through and ink penetration were made (see appendix E)

Roughness measurements 2:6
Another mechanism that also was tested was roughness of the substrates. Tests were made with coated side facing up. Five measurements were made before the instrument automatically calculated the mean value. Clamp pressure that were used is 1 MPa, because it is a standard for offset and newsprint papers. These values were plotted (see appendix F)

Pore structure 2:7
After tests were made they were sent to Dupont who made Mercury porosimetry tests on the substrate. This is plotted as shown in appendix F which show the pore structure of each paper.
Deltack measurements 2.8

Further measurements were done on the same substrates on an instrument called Deltack. It measures ink splitting forces between paper and blanket in the printing nip. These tests were made in order to see how spreading and absorption of particles have a part in ink absorption. In figure 5 you can see typical coated and uncoated curves from a Deltack measurement.

![Figure 5: Ink setting curves can identify capillary, spreading, and “hybrid” mechanisms of ink setting which illustrate structural characteristics of the print surface.](image)

These tests were made by using a method called Mode X where you make ink up on a aluminium form, make a half rotation on the instrument so ink transfers to paper. Aluminium form is removed. After that the test starts again and now the paper rotates against a blanket and the forces that are picked up by making 20 rotations with 4 seconds interval is the force between the paper and blanket. Results in appendix G. This time the reference #3 gloss is not included in the test.

Further tests/group two & three 2.9

After a reliable technique was developed, using group one as substrates, which showed good results, further tests were made on substrates that had different character. Tests were made on group two (test in a narrow range regarding pore structure) and group three (high bulk). All tests were made with the same technique, modified ink mileage and the same settings.

Dupont (group two) substrates were limited for one test. Therefore no Mode X measurements were possible. Except for the deltack all other measurements were made on group two (see appendix H side 1, 2 & 3).

Ink mileage tests were also made on high bulk substrates (see appendix I).
Conclusions

To a large extent you easily can see if a paper has more or less coating and by that you can tell if the substrate is going to give more or less ink hold out. If you make analysis on paper with very similar character you can not see by visualizing if the substrate is going to give you 10% ink penetration or 50%. So by looking at substrates in micro scale and comparing different mechanisms, you can see big differences which can have a big impact on how you should produce a coating to get satisfactory printability and save your customers money.

As mentioned before, printability can not only be determined by looking at density in relation to ink amount. You also have to compare print through in relation to ink applied. In appendix L you can see a typical printability analysis of two papers, where both density and print through is involved. Print through has been divided into two components and the ink penetration has been calculated as a percentage of the paper thickness.

All this calculations are compared to see how the different mechanisms relate to each other. For example one sample can have 40% of ink penetration compared to a similar sample with 15%, see appendix L.

Further studies as the pore volume/size and roughness of paper made for this project should be done to get more understanding of the papers characteristics.

As said before this project has involved three different sets of testing. Group one, two and three. Conclusions are also made after these three sets.

Conclusions after making tests on group one:

Benchmarking analysis seems to work and is consistent with mercury porosimetry results as well as published work on separation of ink components.

Surface smoothness may be the predominant factor for some grade comparisons.

| #5 Gloss | good mileage, excellent ink penetration |
|          | fits with small pores/low volume       |
| #5 Dull  | poor mileage, much ink penetration     |
|          | fits with larger pores/larger volumes  |
| #4 Gloss | good mileage, fair ink penetration     |
|          | fits with »middle of the pack« pore size/pore volume |
| SC       | fair mileage, poor penetration         |
|          | is surface density/filler distribution an issue? Does data capture total surface pore area available for ink penetration? |
On a macro scale, ink mileage is driven by surface smoothness, i.e. rougher surfaces fundamentally require more liquid to cover their surface. For papers of similar smoothness, the size and volume of coating pore structure can play an important role. If you look at appendix G you can see that the curve for SC does not act like an uncoated paper, because there are both spreading and absorption particles in the substrate.

Ink setting curves (Deltack) can identify capillary, spreading, and »hybrid« mechanisms of ink setting which illustrate structural characteristics of the print surface.

Competing mechanisms for ink setting further complicate the analysis. »Hybrid« surfaces containing elements of coated and uncoated absorption can vary widely in their ability to retain ink effectively at the surface.

Conclusions after making tests on group two (see appendix H side 1, 2 & 3):

Group two did not show satisfactory results. The data set is not diverse enough to draw firm conclusions.

• Opacity vs Print Through is on same response line
• Most ink mileage data are very close to 1.0 g/m² at 1.7 density
• Mercury porosimetry data were in a narrow range.
• PPS vs mileage is not predictive in this range

Conclusions after making tests on group three/high bulk (see appendix I):

• There are ink mileage differences among similar grades that cannot be easily explained.
• There is evidence that »High Bulk« coating structures can be produced with the same ink mileage as conventional, most of the time.
• More work is needed to understand the impact of coating pore structure and ink setting mechanisms on this phenomena.

As said before, this report is part of a continuing project. Further tests will be done until International Paper find a way to produce coated products with more ink mileage or less show through than current competitors.
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Reference

Littreture:


Pauler, N (2002) A model for the interaction between ink and paper. STFI, Stockholm

Instrument manuals:


Dürner Herbert, Prüfbau (copy of original manual, available at International paper in Cincinnati)

Internet:

Indiana paper market (2002-08-05) http://www.indianapapermarket.com/glossery.asp#a


Personal communication:

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Appendix A

Prüfbau

1. Printing unit 1
2. Printing unit 2
3. Idler arm on which the aluminum form is first placed
4. Removabel inking roller made by synthethic material/rubber
5. Two temperature-controlled steel distributing rollers
6. Track in which carier is placed in
7. Acceleration and speed settings are made here
8. What pressure you want to print in sets here

Prüfbau measurements

final print on paper strip
Appendix B

Opacity measurements

Thickness of paper

Sheets or paper backed by an infinite surface in a single layer

Reflectance of a back surface through the film

Reflectance of reverse side of the print

R_0

R_x

R_0
Appendix C

L&W PPS Tester / Section through a measuring head.

L&W PPS Tester

5. Protective cover
6. Measuring head
7. Photocell
8. Lower clamping plate. You can chose between soft and hard backing.

Section through a measuring head.
Appendix D

Ink Mileage/GROUP ONE

Calculated Ink Mileage Curves

![Graph showing calculated ink mileage curves for different ink densities and usage.]

log

4 point ink mileage test

![Graph showing log transformation of ink mileage data.]

\[
y = 1.2064 \ln(x) + 1.797; \\
R^2 = 0.9692
\]
Appendix E

Print through/GROUP ONE

Opacity vs Total Print Through

Contribution to Total Print Through
Appendix F

Roughness & Pore structure/GROUP ONE

Roughness

**PPS vs Ink Usage @1.6 Density**

Pore structure

**Pore Diameter vs Pore Volume**
Appendix G

*Ink setting curves/GROUP ONE*

![Graph showing force over time for different ink settings](image)
Appendix H side 1

Result on group two

Ink Mileage

Percent contribution to total print through
Appendix H side 2

Result on group two

Opacity vs Total Print Through

PPS vs Ink Mileage
Appendix H side 3

Mercury porosimetry data in a narrow range
Appendix I

*Ink mileage/GROUP THREE*

---

**IP—Regular vs HB Ink Mileage**

- 32#
- 30#
- 30# HB
- 38#
- 38# HB
- 40# Advofst.
- 30# Super hi-Bulk

**#5 HB LWC**

- Comp. A
- IP-Bucksport
- Comp. B
- Comp. C
- IP-Sartell
- Comp. D
Appendix J

Weight measurements on aluminium forme
### Appendix K

**Time plan**

<table>
<thead>
<tr>
<th>Month</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>May</td>
<td>Literature review &amp; equipment training</td>
</tr>
<tr>
<td>June</td>
<td>Develop &amp; refine ink mileage and print through measuring techniques</td>
</tr>
<tr>
<td>July</td>
<td>Produce data for substrates provided for this project.</td>
</tr>
<tr>
<td></td>
<td>Data analysis &amp; recommendation for pilot trial</td>
</tr>
<tr>
<td>August</td>
<td>Write the report</td>
</tr>
</tbody>
</table>
Appendix L

Typical curves on a printability analysis

Fig. 3. Printability analysis of two uncoated papers