Laboratory Ink Transfer as a Tool to Analyse Waterless Offset

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Keywords: Coated Paper, Waterless Offset, Laboratory Printing, Halftone, Dryography, Screening, Ink Transfer

ABSTRACT

A laboratory offset printing method based on the Prüfbau Printability Tester, called Modified Halftone Offset Control method (MHOC) has been developed to emulate waterless offset printing. The MHOC method includes offset ink transfer in fulltone, as well as in halftones using bearer to bearer nip configuration. The laboratory print results are compared to the offset press print results at similar solid tone inking level using the same materials for different screened halftones in the negative waterless plate making process.

The MHOC dot gain correlate to dot gain occurring in a single pass unit sheet-fed offset press fitted with a compressible offset blanket. Fine screens, when using films for plate exposure, cause an increase in dot gain with negative waterless plates, i.e. dot gain increases from film to plate while dot size decreases. Most important factors for ink transfer in waterless offset relate to phenomena involved during the inking of the printing plate and during the ink transfer from the plate to the blanket. Small halftone dots probably accept and release less ink than large dots. This we found especially true for the printing press, when compared to the laboratory press as the source of difference lies in the inking dynamics of the plate. A fundamental reason relates to the cohesive force of the dryographic inks which is higher than the adhesive force between the ink surface and the printing plate halftone dot areas. Thus, the oleophilic area of the plate is unable to adhere the ink in small dots during inking in the printing press. When using a compressible offset blanket, the coated papers have little influence on dot gain at similar solid ink print density (polarised densitometer) in the waterless offset process.

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Introduction

Laboratory printing equipment should be able to predict commercial printing and give an opportunity to determine the effects for different offset configurations according to prevailing adjustments on a given press.

For laboratory printing, a fulltone transfer is usually made as the interest for halftone transfer is not ordinarily included in the testing. However, Woodall (1991) is suggesting that a laboratory fulltone, or solid black print, yields only a small amount of information on how a paper actually prints on a commercial newsprint press. Conditions of laboratory testing differ according to the specific needs which are mainly those of the ink and substrate manufacturer. The printer seldom has any influence on ink and substrate manufacturing as his main focus is print production. Up to now, newspaper and solid tone letterpress transfer has dominated the ink transfer determinations, e.g. Mangin *et al.* (1982). However, early attempts were made by Oittinen *et al.* (1980) and recently by Barratte *et al.* (1995) to study somehow simplified conventional offset type of ink transfer that included dampening solution. Using dampening solution in a laboratory test is difficult due to problems in reaching and keeping the proper emulgation level of the dampening into the ink. In essence, simulating the dynamic situation of a conventional offset press in the laboratory is very difficult to reproduce. Furthermore, evaporation of the dampening occur while weighing, as a slow process (upto a minute), is made to evaluate ink transfer. This is one of the origin for variations in the measurements. Finally, there has not been, before present work on waterless offset, any correlation shown between laboratory offset ink transfer in halftones and that of a real offset press.

Techniques characterising coated paper are reviewed by Wygant *et al.* (1995) who imply also that current printability testers need to be reengineered to run in the offset instead of the letterpress mode. Hoc *et al.* (1995) introduced a method for waterless offset with the addition of halftone ink transfer. The method is called HOC for Halftone Offset Control method. The HOC method, further modified in the present work to become the MHOC (Modified Halftone Offset Control method) provides a better correlation to sheet-fed offset printing by using a bearer to bearer configuration. Nordström *et al.* (1997) have done some additional determinations of ink transfer and studied the influence of matt and glossy coated paper for laboratory letterpress and waterless offset configurations. Ink transfer, print density and print gloss were determined and evaluated with mathematical estimations. The work also included waterless offset ink transfer in 133 lpi screen halftones. However, the configuration related to applying standard pressure in the Prüfbau printability tester configuration (HOC), while the present work uses a bearer to bearer configuration (MHOC).

The potential thus is with MHOC to investigate on a laboratory level the influence of inks, plates, blankets and substrates as in a press configuration. Ambient printing conditions for sheet-fed purposes can then be varied according to a certain press defined configuration, with the added advantage of including halftone screens, or material directly from the waterless press. This is performed with a small quantity of available materials, which is for laboratory testing a benefit, but it remains somewhat restrictive targeting a real printing process due to the relatively small printed areas. However, for example small series of laboratory made inks and substrates can be studied on a more realistic level. Trouble-shooting opportunity also exists, as all materials can be used directly from a press, configuring the set-up used on the offset press upon the laboratory equipment for waterless offset. This laboratory approach will point out fastly the potential source of variation with less expenses than press testing. Investigations on different materials and various physical adjustments at different environmental conditions will then be easily determined on a laboratory level, prior to making drastic changes in full-scale print production.

Materials and Methods

The same materials were used in the offset press and in the laboratory. The plates for laboratory were cut from the same printing plates that were run on the press.

Two commercial woodfree double coated papers (WFC) were evaluated. The base-paper was made on the same papermachine (hybrid former). Only the off-line coated top-coating properties (applied on the on-line metered size-press pre-coated base) were altered by adjusting coating and calendering techniques, *Table 1*.

Table 1. Manufacturer reported data of coated papers

Coated paper type	**Matt**	**Glossy**
Basis weight	115 g/m^2	115 g/m^2
Caliper	105 μm	82 μm
Roughness (PPS 10)	4.5	< 0.9
Gloss, Lehmann 75°	15 %	80 %
Opacity	95 %	93 %
CIE-Whiteness, 457 nm	109	109
Tensile strength index, MD	5.38	5.90
Tensile strength index, CD	11.22	11.73
Tensile strength index CD/MD	2.09	2.00

The values in *Table 1* are from the paper producer reports to a printer. They are to be considered as target values as no information is provided on the possible variations occurring during paper production. The printing was done in the paper machine cross direction (CD), on the same paper side. The samples were taken randomly from a pile of sheets, from the middle of the stack as sold and delivered by the sales organisation. No information was gained on the type of sheeting procedure used.

For plate imaging, the film made in pre-press was a hard film suitable for small halftone dots to obtain a solid density between 3.96 to 4.14. The printing plate was a negative processed waterless offset plate, processed in the same conditions for all screens. The silicone-based oleophobic layer thickness, from the top to the base of the oleophilic image area on the plate, was reported from the manufacturer to be between 1.5 to 2 μm deep with an accuracy of 5 %. A plate processor was used during the development of the plates. Cut-out samples of the plates run on the press were mounted on a conventional Prüfbau aluminium printing disk by using a self made fastening construction and double sided adhesive tape.

The rubber blanket was 1.95 ± 0.02 mm thick three-ply cotton fabric, compressible type used for slow sheet-fed printing. The blanket had a two ply underlay construction, air-filled foam in the middle, and one ply fabric underneath the three layered rubber based top-layer. The fabrics, mainly cotton, were additionally covered with adhesive as could be examined with a light microscope. The blanket ink transfer %, or manufacturer stated ink release, was reported to be 60 %; the mechanically ground surface roughness between 0.6 and 0.8 μm (R_a); the compressibility 4.5 %; the hardness of blanket top layer material 77 Shore A; and the stated construction recovery time of 35 ms after an imposed impression, or squeeze, of 0.1 mm. According to the manufacturer, the suggested blanket nip pressure should be between 80 and 150 N/cm^2 , i.e. when adjusted by the operating impression distance, and the tension applied to the blanket. The operating range, i.e. adjustable impression, for this type of blanket is said to be between 0.1 to 0.25 mm squeeze. The blanket was glued to the Prüfbau printing unit carrier base, which is a flat plate of composite plastic, with a slight stretch, approx. 0.5 % of the blanket length. The plastic carrier base plate was adjusted so that the calculated printing pressure, as measured by nip impression width (nip length in printing direction), would be similar to that of the printing press last inking unit. Practically the impression squeeze was 0.14 mm for the Prüfbau carrier base and 0.10 mm in the offset press, or a 6 mm nip impression width for both (an area of 240 mm^2 in Prüfbau). Calculations were based on the radius measured from the cylinders in the press and Prüfbau roll, and using an infinite radius for the flat offset blanket on the carrier base plate in the Prüfbau. While using a compressible blanket at 0.04 mm difference, the nip pressure could probably be seen as similar, and due to bearer to bearer configuration independent on the pressure applied in the Prüfbau (adjusted to 100 kp, i.e. approx. 1000 N in both units). The blanket was hand-washed between all laboratory printing trials using a commercial petroleum-based blanket washing liquid, followed by ethylalcohol and finally by pure acetone using clean cotton cloths, assuring that no ink rests were present from a previous ink transfer.

The ink properties are reported in the *Table 2* and run at 25-27 °C during the trials. No information on ink component content, manufacturing procedures and rheological determination was obtained.

Table 2. Manufacturer reported data of the black ink

Hartmann Offset S7000	**IRODRY**
WS/EL	8
Lasur/Transp.	■
Spirit	+
Nitro	+
Alkali	+
Penetr.	+
Oxid.	+

Batch nr. 66 25 25 37, Kasten Frisch

The inking unit in the Prüfbau laboratory printing unit was running at a constant speed of 0.5 m/s (measured as 0.491 m/s) and temperature controlled at 26 °C. A weighing balance accurate at ±0.1 mg was used. By knowing the areas involved, estimating the gravimetrical density of the ink to 1 kg/dm^3, and by weighing the amount applied and transferred, calculations for the ink amount transferred in g/m^2 (in the inking system, on the plate, on the blanket and on the substrate), or as an ink film thickness, were thus estimated. The ink was distributed in the inking system for 30 s, then the plate inked for 20 s. The next 30 s were needed to lift the roll, and stabilise the balance to determine the weight of ink on the fulltone roll prior to transfer. By measuring the ink transferred from the plate, and in offset mode transferred to the coated paper situated on the second print station (generally used for set-off measurements in the Prüfbau) around the hard aluminium roll the ink amount transferred to paper was determined in g/m^2 for the fulltone coverage. Equal ink film thickness in each print was assured by measuring print density 100 s after ink transfer (Gretag D186, Gretag AG, Regensdorf, Switzerland).

The Normal Colour Intensity (NCI) index, introduced by Schirmer and Renzer (1971), was determined from eight different inking levels. The density measurements for the NCI index determination was done by using the Gretag D186 densitometer. This type of a densitometer is not recommended by Schirmer and Tollenaar (1973) because such polarising densitometers provide results that are not in agreement with visual examination. This consideration is probably more important for process ink (CMY) determinations than for a black ink (K) used in this work. The polarised densitometer, Gretag D186, was used due to the interests in withdrawing the effects arising from the coated substrates and involved print gloss. The information obtained by minimising effects from gloss of different inking levels for the black ink on the matt and glossy coated substrates is thus more appropriate.

After choosing a solid inking density (SID) level of 1.65 (pooled std.dev. 0.045) for the optimal NCI level which was valid for all screenings, the dot gain measurements were made from 3 randomly picked samples and are reported as a mean value.

Results

Exposure of the waterless negative plate

As seen in *Figure 1* , dot gain from film to plate increases when line screening becomes finer. The AM (amplitude modulated) shows less influence than FM (frequency modulated) on dot gain from film to plate with a value for the middle tones ranging between 10 % and 20 %, when investigating AM line screens between 133 and 300 lines/inch. The FM dot gain from film to plate ranges between 20 % and 50 % in the middle tones for dot sizes from 31, 21 and 14 µm respectively. During the film output from the RIP (raster image processor) equipment the result is not stable for the 3600 dpi, when compared to 2400 dpi, which thus influences also the plate exposure results and gives a lower maximal dot gain in the following print result.

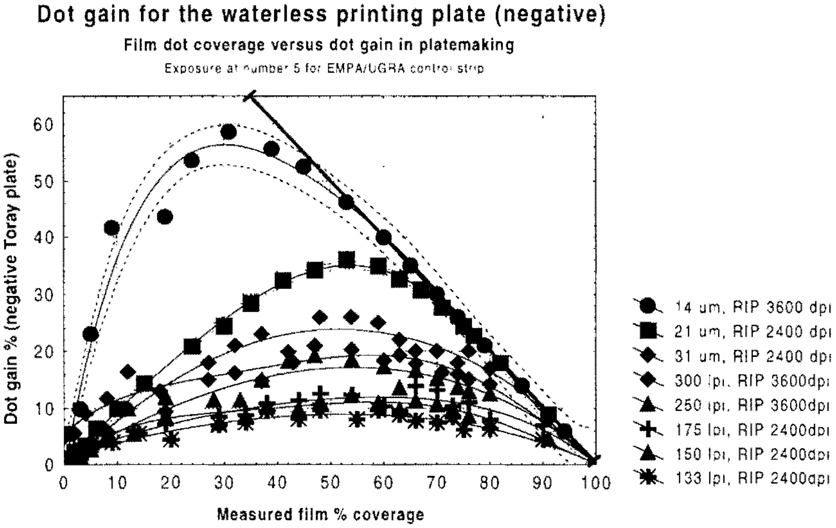
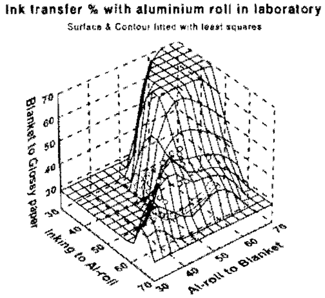


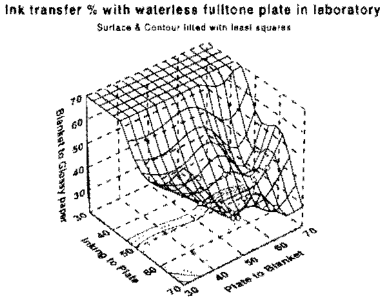
Figure 1. Dot gain increase from film to waterless negative plate

Fulltone ink transfer

As seen in *Figure 2* , ink transfer in fulltone between the smooth aluminium roll for Prüfbau printability tester and the fulltone waterless plate attached to the Prüfbau roll are different. While changing the inking level the transfer % in the case for the Prüfbau aluminium roll change more in a linear manner from the inking to the plate, from the plate to the blanket, and from the blanket to the substrate. The waterless plate image area seems to affect transfer % more during inking and ink release from the plate to the blanket, i.e. the transfer is less affected from blanket to substrate at different inking levels. The inking of the plate is done with approximately 50 inkings prior to ink transfer to the clean blanket and to the substrate in single transfer pass. The inking system rubber roller may absorb some oil influencing the level of the transfer %.


Ink transfer % with aluminium roll in laboratory

Surface & Contour fitted with least squares


Ink transfer % with waterless fulltone plate in laboratory

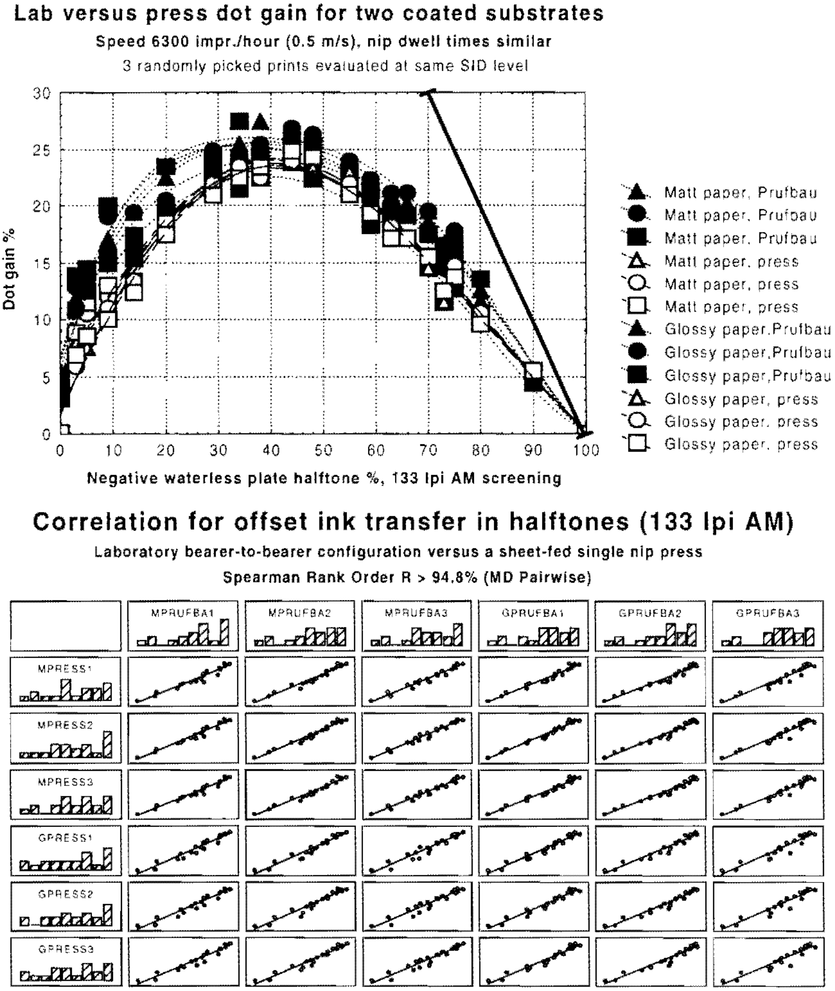
Surface & Contour filled with least squares

Ink in inking (g/m^2)		Print Density	
Al-roll	Plate	Al-roll	Plate
2.9323	2.0472	0.98	1.02
3.2990	2.4794	1.02	1.10
3.7743	2.9659	1.08	1.05
4.2384	3.2972	1.16	1.14
4.6332	3.8080	1.15	1.13
5.1123	4.3376	1.29	1.35
5.5595	4.5958	1.28	1.42
5.8177	5.1665	1.30	1.43
6.0704	6.0591	1.32	1.65
7.0060	6.5157	1.42	1.67
7.9678	6.9368	1.58	1.63
8.6695	7.6628	1.65	1.68

Figure 2. Fulltone ink transfer % differences (aluminium roll, waterless plate) in laboratory offset ink transfer (MHOC).

Amplitude modulated screening (AM)

The correlation between press and laboratory results is high ($R^2>0.93$ for the line screens 133, 150 and 175 lpi, i.e. processing the films with a 2400 dpi RIP). No significant difference exists between the coated papers. At similar solid ink density level, plate to paper dot gain reaches a maximum of 25 % dot gain for 133 lpi screening, *Figure 3*. The deviation for the laboratory prints is slightly higher when compared to the press dot gain results.



M = Matt coated paper; G = Glossy coated paper; Press = Offset printing press; Prufb = Laboratory offset transfer; 1, 2 and 3 = Randomly picked samples

Figure 3. Correlation for laboratory and press (133 lpi).

The plate to paper dot gain from the laboratory results is very different from press results for high screens, i.e. 250 and 300 lpi. It is approximately 20 % for the press and 45 % for the laboratory configuration at 300 lpi, see *Figure 4*. The main reason is in the inking of the plate and the ink transfer from plate to blanket. Laboratory plate inking gives approx. 12 times more inking passes (i.e. contacts between the inking roller and plate) to the plate prior to transfer. Some deviation between the coated papers is found for the press results at the low halftone covered areas. The difference seen on 300 lpi screening between the theoretical maximum (thick line at the dark tone area in *Figure 4*) is attributed to deviation during pre-press work, i.e. the film making process for 3600 dpi resolution. At 20 % plate tone area (indicated in *Figure 4* by ellipses) similar deviation for both press and laboratory results is observed. These deviated dot gain values may have been caused by variation in the plate polymer layer properties, probably affecting both exposure and processing of the plate while using a film, which may also have affected the ink transfer. The film showed no defects in this area.

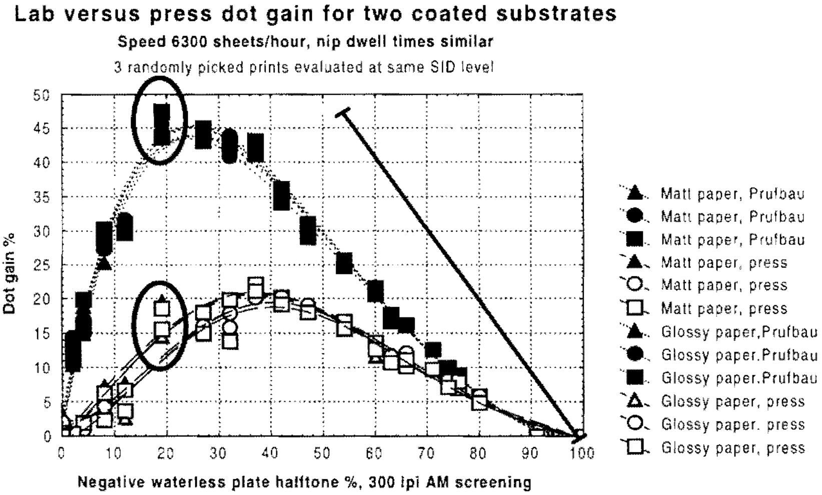
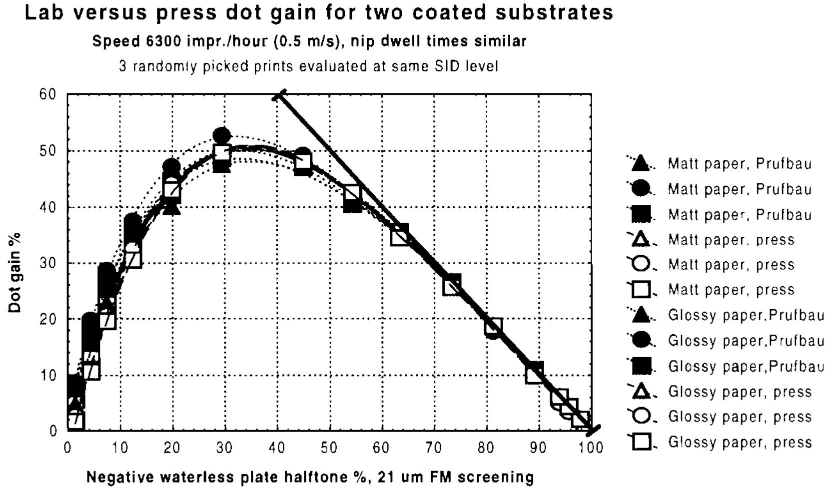


Figure 4. Dot gain differences between laboratory and offset press due to prevailing differences in inking of the plate (300 lpi).

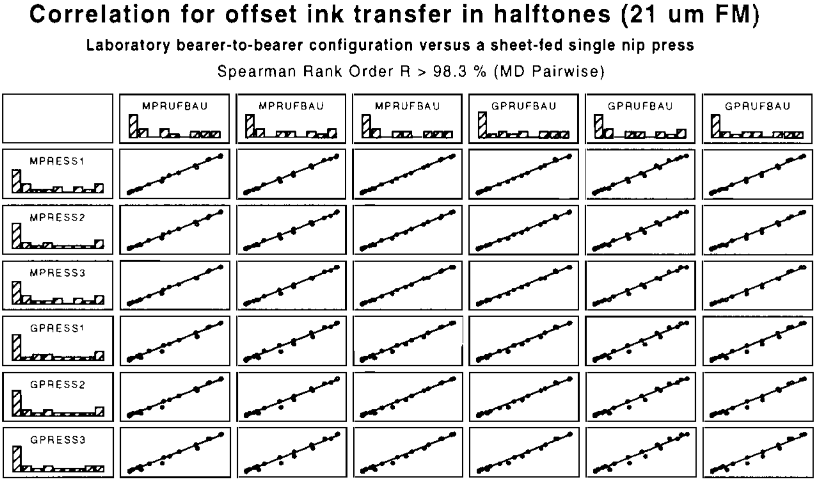
Frequency modulated screening (FM)

The plate to print dot gain shows high correlation for both 31 and 21 µm FM screening. As seen in *Figure 5* , the filling-in of the uncompensated 21 µm FM occurs already at 55 to 60 % plate tone. The laboratory test results show a slightly higher deviation than those of the press. No differences is seen between the coated papers, while the glossy coated is more prone to deviation than the matt coated paper.


Lab versus press dot gain for two coated substrates

Speed 6300 impr./hour (0.5 m/s), nip dwell times similar

3 randomly picked prints evaluated at same SID level


Correlation for offset ink transfer in halftones (21 um FM)

Laboratory bearer-to-bearer configuration versus a sheet-fed single nip press

Spearman Rank Order R > 98.3 % (MD Pairwise)

M = Matt coated paper; G = Glossy coated paper; Press = Offset printing press; Prufb = Laboratory offset transfer; 1, 2 and 3 = Randomly picked samples

Figure 5. Correlation for laboratory and press (21 µm).

The samples at 300 lpi AM screenings, *Figure 4*, and the 14 μm dot size in FM, *Figure 6*, show similar trends. The 14 μm screened plate area seems to reject the ink and transfer the ink unevenly both in laboratory and, with even more deviation, on the press. It is probably because the 14 μm FM screening has equal dot sizes, *Figure 6*. Therefore this effect, already shown for 300 lpi screen, prevails over the whole tone range. The inking problems are more accentuated in the press, and somewhat less in the laboratory. Slight differences between the papers can be found on the press.

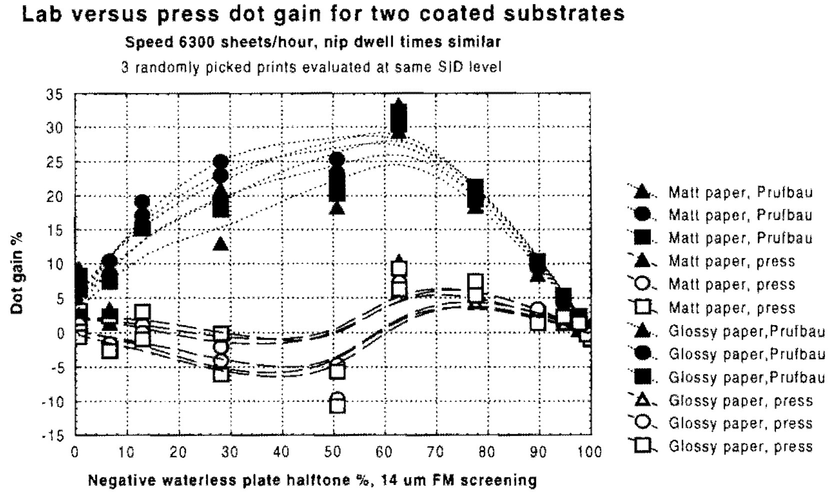


Figure 6. Dot gain differences between laboratory and offset press due to too high cohesion in the ink during inking of the plate (14 μm dot size), or a poorly exposed and processed plate.

Discussion

The plate making process induces variations in the halftone dots, and careful plate processing and cleaning is thus required. Otherwise there may be residues of un-removed polymeric material in the exposed halftone areas after the plate development process. The halftones will otherwise not transfer ink properly, as seen for example in *Figures 4 and 6*. The problems while going towards fine screens are related to film quality, dot quality on film, exposure of the waterless plate, plate developing process, the polymeric layer thickness, and the optical properties of the polymeric layer of the waterless printing plate. Computer to plate/press/print (CTP^3) processes, i.e. no films, are one way of reducing these problems.

The smaller the halftone dots get, the more crucial all process parameter deviations, which reflect upon the final print result and quality. The ink transfer to plate may be restricted to a certain area of a halftone dot, i.e. adhesive force prevailing between plate surface and ink surface, depending on the cohesive force development in the ink during inking of the plate. The cohesive forces in the ink may differ at the various shear rates the ink is exposed to, i.e. different inking/printing speeds. Thus rheological determinations at accurate temperatures for realistic film thickness, e.g. 5 to 0.5 µm, and various shear rates may be necessary to determine if one wants to accurately describe the behaviour of the ink in a waterless offset press. The cohesive properties may be adjusted by ink formulation and temperature control of the ink, e.g. for each plate separately on a press. A better solution would be to adjust temperature for zones or areas/spots, obtaining different temperatures upon the printing plate according to the type and area coverage of the chosen screening, i.e. halftone dot size. Thus FM screens (frequency modulated) having the dots of equal sizes would be easier to control by temperature areas according to image area coverage on plate, while AM screens (amplitude modulated) with different dot sizes would require even more an image area coverage related temperature control on plate. Areas of small individual dots may require different temperatures than large areas of close to fulltone coverage to assure accurate ink acceptance and release to the plate, and thereby best obtainable print quality. Such a temperature control procedure has not yet been established, as far as we know, on a commercially available printing press.

As all laboratory methods, the MHOC laboratory method also has restrictions. The ink transfer occurs in a single pass with clean materials and the inking of the plate is different to the inking on a press. A desired ink temperature can only be adjusted within the inking of the plate in laboratory if the ambient room temperature is controlled according to substrate requirements, i.e. 23°C and 50 %RH. The inking of the plate is also done with several inkings, e.g. inking 20 s gives approx. 50 inking hits to the plate in laboratory, when comparing to the 4 hits in the press, before ink transfer is made to the blanket and to the substrate. Present results are also obtained with compressible blankets, whereas differences may arise for the coated papers using harder blankets. Despite these minor drawbacks, the MHOC method configured on a Prüfbau printability tester seems worth using in characterising the waterless offset ink transfer in laboratory.

Conclusions

The laboratory MHOC method correlates well with a single inking station in an offset press when transferring halftones in 133, 150 and 175 lpi AM, in combination with 31 and 21 μm dot sized FM screens and a compressible offset blanket in a bearer to bearer configuration.

While using films at the pre-press stage, plate exposure and processing need individual configurations for each type of screening used, according to the polymeric oleophobic layer properties on the waterless plate. For example, if the waterless plate oleophobic polymer layer thickness deviates, or changes in its optical properties, the influence on dot gain may come from either plate exposure (when using films), or further on during the ink transfer. In the waterless plate processing, the removal of polymeric material is difficult to control at high screen rulings. The smaller the halftone dots, i.e. when line screening increases, the more influential the ink-plate-blanket interactions. This, in combination with temperature effects within the waterless offset, may tighten the "working temperature window" for the used inks, i.e. their rheological/chemical properties. To conclude, it is crucial to accurately control the process parameters involved, i.e. ink, plate, blanket, and press adjustment, when working on high screen rulings in waterless offset because the process is influenced by different effects, or combination/cumulating of many effects.

With a compressible offset blanket, the halftone dot gain in waterless offset, i.e. ink transfer from plate to blanket and from blanket to the substrate, is less related to the substrate properties, here coated paper. The dominating effect for dot gain in the waterless process may thus already be prevailing on the blanket, before the transfer of the ink from the blanket to the substrate. Differentiating these details into individual process stages, for example by dot gain measurements, as was done in this investigation, is beneficial: i.e. one gains a better knowledge and control on where exactly a certain phenomena occurs in the waterless offset process.

The waterless process itself gives rise to possibilities of constructively differentiating the areas of improvement. This is mainly due to the lack of dampening solution and questions on how to keep accurate/known emulgation of the dampening solution into the ink. The waterless process thus provides the potential to achieve the highest possible print quality in offset ink transfer. By understanding the waterless offset limits and possibilities we will be able to use the advantages to prevailing, and future offset printing processes.

Acknowledgements

This work was financed by the Swedish Paper & Board, and the Swedish Graphic Arts Industries, through the Print Research Program (PFT-programmet). Ms. Martina Stål (Tidningsutgivarna/Färgpressen, Stockholm) is thanked for the practical aid within the pre-press work. Professor Patrice Mangin (Royal Institute of Technology, Stockholm, Sweden) is acknowledged for constructive comments and linguistic aid during the preparation of the manuscript.

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