Ink transfer in flexo evaluated by X-ray fluorescence

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Abstract

Flexography has shown a dramatic rise in print quality and it is more important than ever to understand the process and to identify those parameters which affect the print result. For full control over the ink transfer it is necessary to measure the ink amount on the anilox roller, the printing plate and the paper.

In this paper, the use of X-ray fluorescence for measuring the amount of ink on the plate and paper is discussed. The results shows that the technique seems to be very suitable for this purpose, particulary because of its easy performance and high accuracy.

Earlier studies have shown that IR-technology can be used for on-line studies of ink transfer in a flexo press. However, this paper also describes different methods that can be used for measuring the ink film thickness and suggestions concerning further investigations.

Keywords

Flexography, ink transfer, on-line, X-ray fluoresense, infra-red, photo-acoustics, optical triangulation

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Introduction

Flexography is a wide spread technology in the printing industry today. Traditionally it has been used for low quality printing, where the mechanical properties of the substrate were more important than the printability. However, the last ten years have shown dramatic improvements in the print quality due mainly to developements in the following seven areas:

- Printing press
- Anilox roller
- Plate
- Ink
- Mounting system
- Chamber ductor system
- Pre-press

The quality can sometimes be almost the same as that achieved in offset or gravure. It is possible to print with four colours, so called process flexo, with screen rulings up to 150 l/inch or even higher. Thus, high print quality can be achieved with flexography today but the goal of the print industry is to optimize the process and to avoid perturbations during the production. To run the process with an optimal result, it is necessary to understand the factors and circumstances which affect the ink transfer from the ink tray to the substrate is affected, and the magnitudes of the effects.

There is no standardized method for evaluating ink transfer in flexo today. On-line studies has been made using an IR-camera (Lindholm and Ström, 1995). The results show that an IR-technique can be used for this purpose but that further developments are needed. Generally, the readings from the on-line systems are only relative, which means that it is necessary to have a system for calibration.

A method for taking samples from a flexo press for calibration was developed which works out up to a speed of up to 200 m/min. It is necessary to stop the press within a half revolution of the plate cylinder. A plate section that has been inked by the plate can then be taken before it has delivered ink to the paper. In the same way, a plate sample that has delivered ink to the paper can be taken before it takes up more ink from the anilox roller. The absolute ink amount on the plate was measured off-line gravimetrically. Although the results were encouraging, the gravimetric method is not practical for frequent use because of problems due to decrease in weight of the plate because of solvent evaporation. Therefore a more rational method is needed. The

gravimetric method can however be used for the calibration of other methods.

Measurements of the amount of ink transferred to the substrate have been studied earlier (Kolseth and Lagerstedt, 1995; Heintze and Kocman, 1992). Both atomic absorption and X-ray fluorescence have been used to determine the ink amount. For these techniques it is necessary that the ink contains a metal which can be detected.

The main aim in this investigation was to evaluate whether X-ray fluorescence equipment was suitable for off-line studies of ink transfer in the flexo process. The technique was to be used for measurements both on plate samples and on paper samples. Gravimetric measurements were used for calibration of measurements on the plate and an atomic absorption technique was used for calibration of measurements on the paper.

This project has been carried out within the Swedish cooperative Print Research program (PFT) which concerns printability, print quality and runnability.

Theoretical approach to ink transfer

In order to describe the flexo process, the ink film thickness must be measured in several places in the flexo press, see figure 1, on the anilox roller before and after the first nip, on the printing form before and after the printing nip and on the printed substrate.

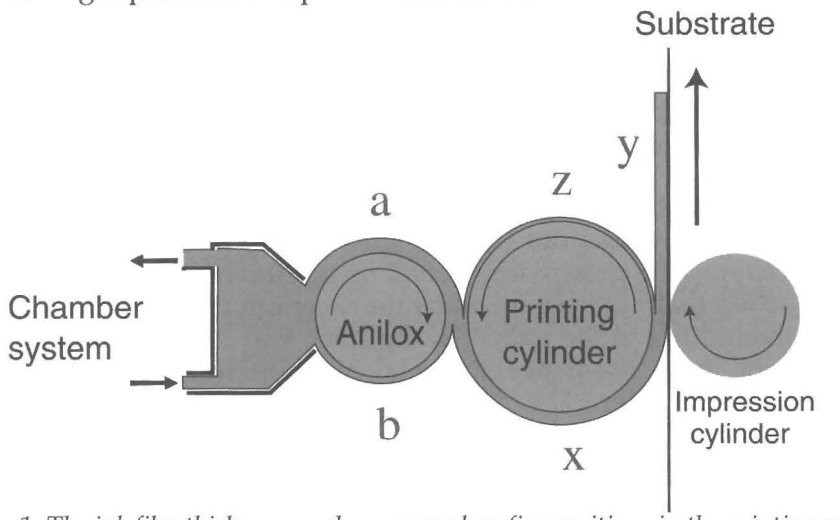

Figure 1. The ink film thickness can be measured on five positions in the printing unit.

The situation can be explained by a basic mathematical approach. The principle of the conservation of matter leads to the following equations:

$$a + z = b + x \quad (1)$$

$$x = y + z \quad (2)$$

where a is the ink volume on the anilox roller before the first nip
b is the ink volume on the anilox roller after the first nip
x is the ink film thickness on the plate before the printing nip
y is the ink film thickness on the paper
z is the ink film thickness on the plate after the printing nip

Five unknown parameters and only two independent equations give that it is necessary to make measurements in three different places in order to solve the system.

The value given by the manufacturer for the anilox roller can be used if the cell volume is measured correctly. In that case the number of unknown factors is reduced by one and only two measurements are needed to characterize the complete transfer of the ink in the press.

A number of different techniques for the measurement of the ink film thickness in the flexo press are described in the appendix.

The test printings

Test printings have been performed in the IMT flexopress which has a web width of 500 mm and a print length of 600 mm. The press can run at a maximum speed of 600 m/min and prints from reel to reel. The press has two printing units which are equipped with chamber ductor systems.

Three different inks were printed at 80, 100, 150 and 200 m/min. Samples from both the plate and the paper were taken out of the press for off-line studies of the ink transfer.

The anilox roller used in these tests was divided into three zones with different cell depths distributed in the lateral direction. The theoretical depths and cell volumes given by the roll manufacturer are shown in the table. The anilox screen ruling was 80 lines/cm for all three zones.

	zone 1	zone 2	zone 3
Cell depth [µm]	25	35	45
Cell volume [cm^3/m^2]	8	10	12

The relative humidity was 50 % and the temperature was 23°C. The impression was 50 µm in the nip between the anilox roller and the plate and 100 µm in the printing nip.

Plate

The plate was a standard photopolymer plate with a thickness of 2,84 mm and a hardness of 50° Shore A. The test form consisted only of full-tone areas.

Inks

Three conventional water-based flexographic inks, coded A, B and C, from different manufacturers were used. The colour was cyan and the water content of each ink was 50 %, 55 % and 68 % for inks A, B and C respectively.

Paper

The paper used was an uncoated white-top liner with the following paper properties.

Property	Value
Grammage	140 g/m^2
PPS-5	6,68 µm
PPS-10	5,52 µm
PPS-20	4,76 µm
pH on surface	4,95
Water absorption, Bristow 0,45 s	7,5 g/m^3
Water absorption, Cobb 30 s	26,8 g/m^3

X-ray fluorescence (XRF)

The principle of the X-ray fluorescence method is that the radiation from an X-ray tube excites fluorescence radiation from a sample. The technique requires inks that contain elements which give strong fluorescence response signals, e.g. metal particles. A diagram over the instrument is shown in figure 2.

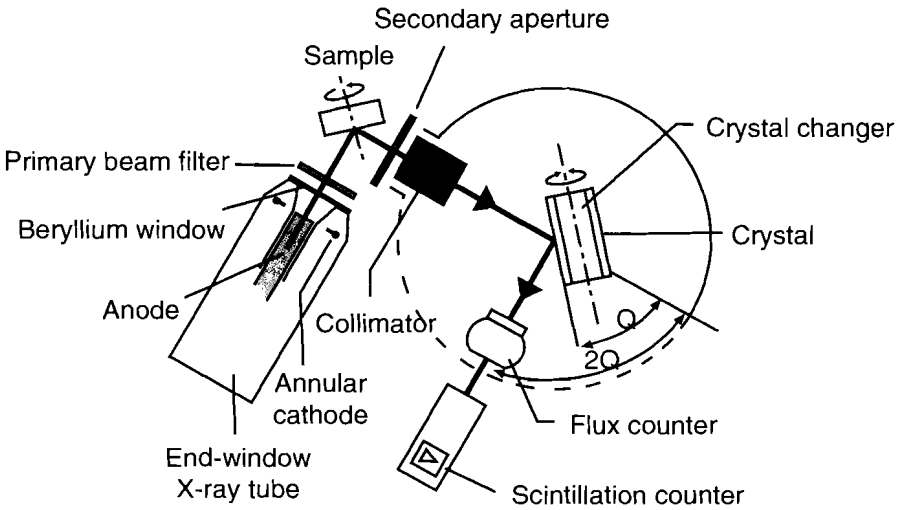

Figure 2. Diagram of X-ray fluorescense equipment.

The X-ray beams strike the surface of the sample and the emitted fluorescence energy is measured and converted into an intensity value which corresponds to the amount of fluorescent material present. A collimated beam of the fluorescence radiation is selected and directed to the center of an analyser crystal which diffracts the light and sends it to a detector. The detector consists of a scintillation counter and a flux counter and gives the amount of fluorescence radiation emitted by the sample during a given time interval. It is possible to calculate the contents of the detected particle in the sample and to deduce the thickness of the ink film.

The sample is placed in a metal holder in which a circular aperture has been cut. It is important that the sample presents a flat surface to the beam to avoid optical perturbations in the measurement. Depending on the size of the sample, the aperture diameter of the container can be from 1,5 to 3,5 cm. For these tests the larger aperture was used because it gives the most accurate values.

The X-ray fluorescence method requires a preliminary calibration which is described below.

Calibration - ink on plate

Calibration was achieved by weighing a plate sample without ink before mounting it in the press and weighing it after printing with dried ink on it. A comparison between these two measurements and compensation for the water content gave the wet ink amount on the plate during printing.

The samples were weighed on a precision balance with an accuracy of 0,1 mg. The mean area of these plate samples was 50 cm^2, and the mean weight was 13,5 g.

Calibration - ink on paper

The measurement of ink on paper was calibrated using an atomic absorption technique. The paper samples were dissolved in concentrated HNO_3. The solution was then burned in a graphite oven and the content of copper was determined by a spectrophotometer. The instrument was a SIM 6000.

For this purpose, it is necessary that the ink contains a metal that can be detected by the spectrophotometer. The cyan pigments used in this study contained a copper atom that gives the green-blue color. However, if the ink contains no metal, it is possible to dope the ink with lithium sulphate in small quantities.

Results

Figure 3 shows the relationship between the XRF and the gravimetric measurements on the flexo plate for inks A, B and C. There is a high degree of correlation (Ra-values within a range of 0.99-1.0), and it is clearly possible to use the XRF-value as a measure of the ink quantity on the plate. The regression lines are however dependent on the ink used, since the fluorescence response is highly dependent on the proportion of fluorescent material in the ink.

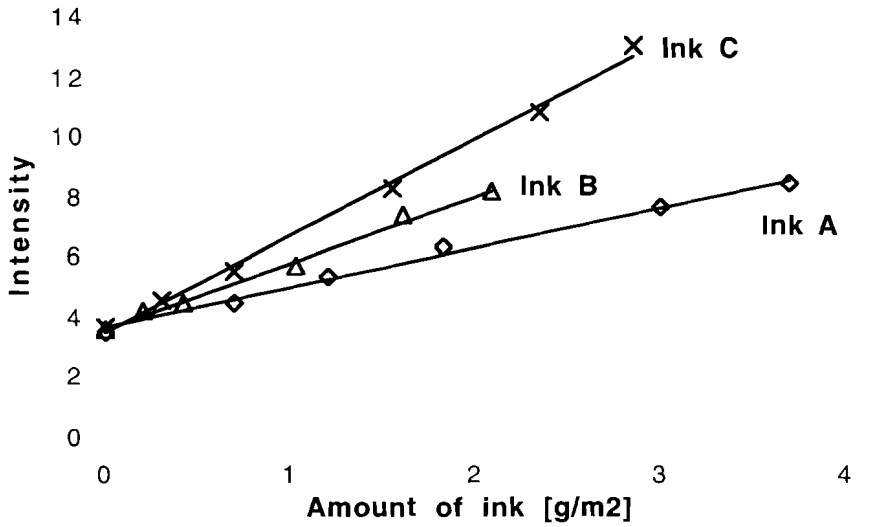

Figure 3. XRF intensity on the plate for inks A, B and C as a function of the amount of ink.

The intensity can be normalized according to the 0-value for the ink amount and the Cu-content of the inks. Figure 4 show that the normalization works for inks A and B but not for ink C.

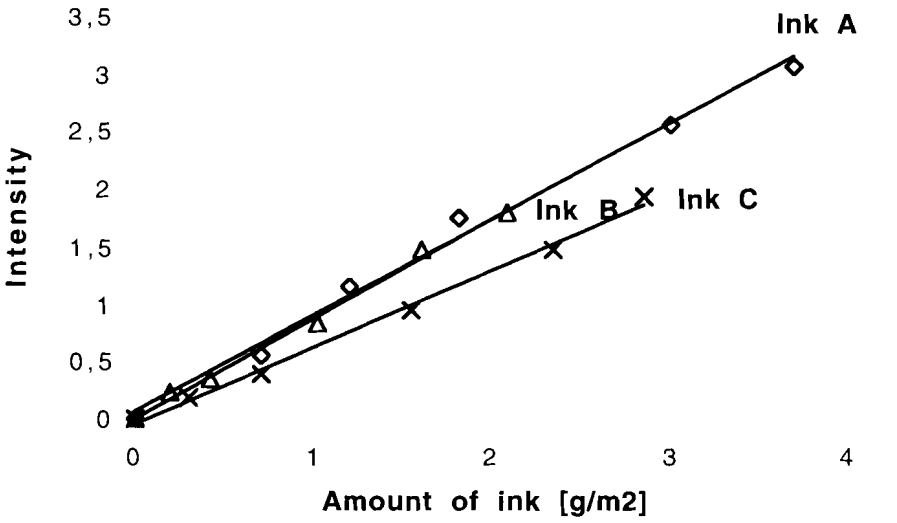

Figure 4. Normalized XRF-intensity.

Figure 5 shows the relationship between the XRF-measurements and the atomic absorption measurements on the paper for inks A, B and C. Unfortunately the atomic absorption measurements did not succed

properly so the following ink transfer curves are based on XRF-measurements on plates, before and after the printing nip.

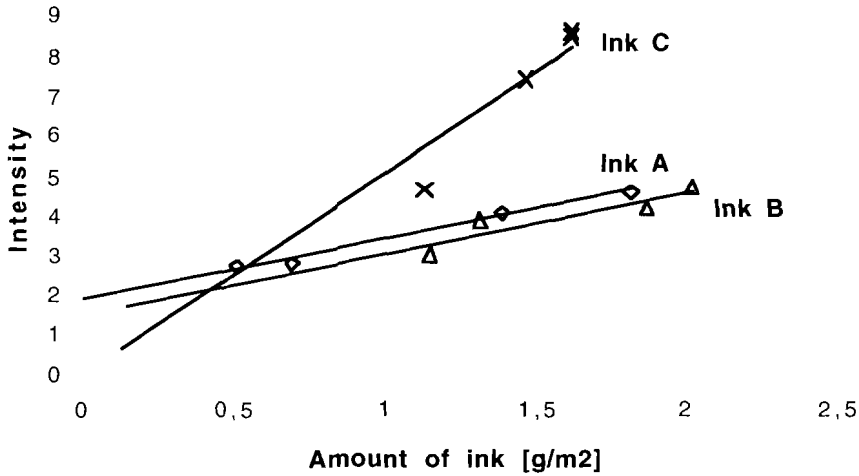

Figure 5. XRF intensity on the paper for inks A, B and C as a function of the amount of ink. Unfortunaly, the calibration curve for ink C was not sufficiently good.

The ink transfer from the anilox roller to the plate is shown in figure 6. The curves will reach the x-axis around 4 g/m^2 which corresponds to the part of the ink that is located at the deepest part of the anilox rollers cells. The relative ink transfer is shown in figure 7. Note that there is a maximum around 10 g/m^2.

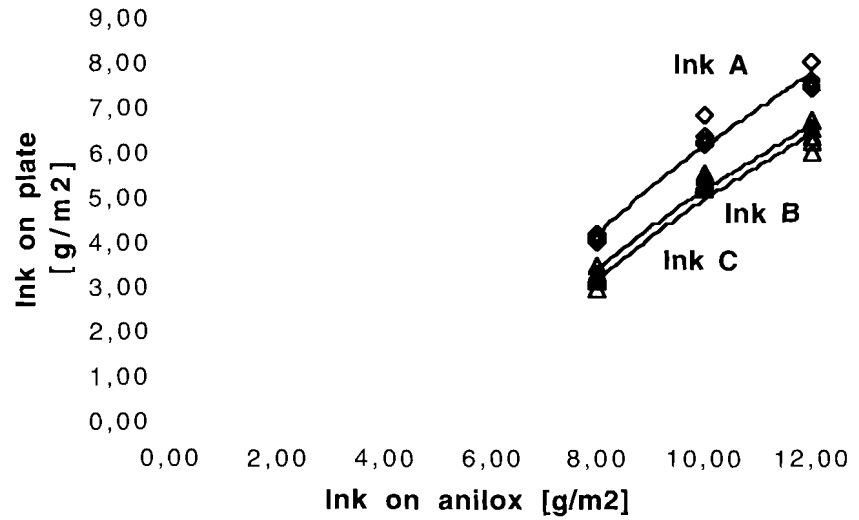

Figure 6. The ink transfer from the anilox roller to the plate.

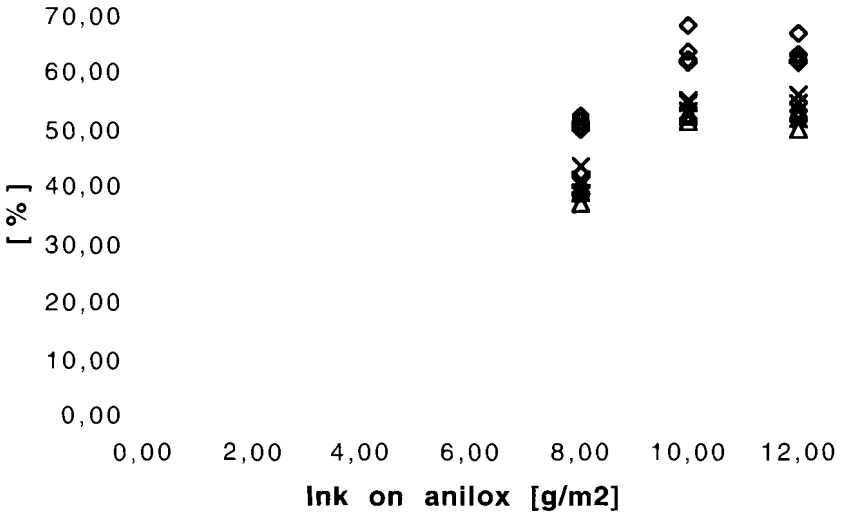

Figure 7. The relative ink transfer from the anilox roller to the plate.

The ink transfer from the plate to the paper is shown in figure 8. The resultis based on XRF-measurements on the plate before and after the printing nip. The relationship is linear. The low transfer for ink A corresponds to samples taken from a press speed of 80 m/min. The relative ink transfer is around 75-80 %, which is shown in figure 9.

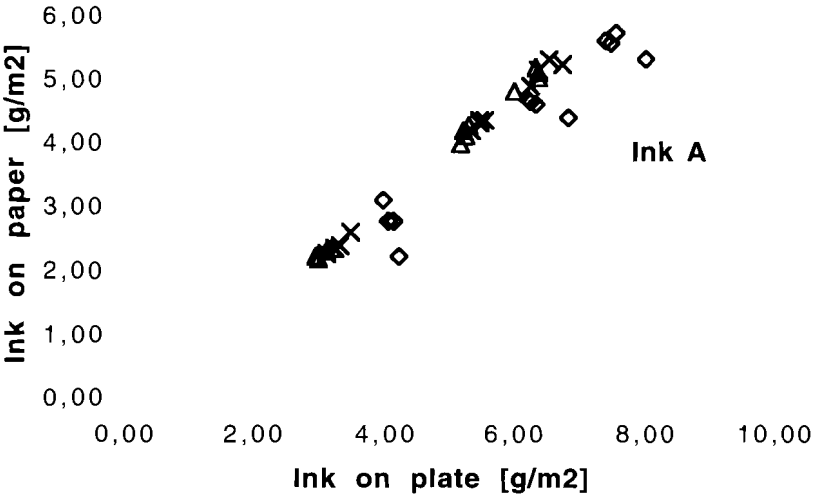

Figure 8. The ink transfer from the plate to the paper.

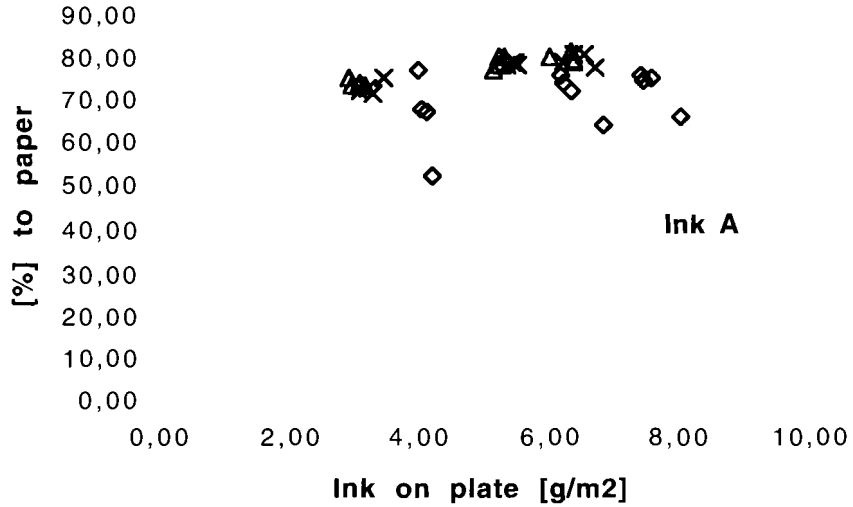

Figure 9. The relative ink transfer from the plate to the paper.

Discussion

The Ra-values for the XRF measurements on the plate were very close to 1 which means that the correlation was high with the gravimetrical measurements. This curves can be used for further XRF-measurements on this plate material when using one of the inks included in this study. It also indicates that a smaller group of samples, can be used for calibration, especially due to the fact that the curves tend to pass through origo. Maybe it is possible to use only one measurement for the calibration.

The Ra-values for XRF measurements on the paper were unfortunately too low. That is because of two reasons. First, the samples that were evaluated with XRF were not physically the same as those that were evaluated with the atomic absorption. It is possible that the differences between the samples had a great impact on the low Ra-values. Secondly, only four samples were chosen for this evaluation which probably was a too small group.

However, it is not necessary to calibrate the XRF measurements at all. The equipment can be used only to achieve relative values of the ink amount for calibration and evaluation of on-line measuring methods.

Conclusions

This main goal of this study was to see whether X-ray fluorescence can be used for ink transfer evaluation in flexo. The following conclusions can be drawn:

1. X-ray fluorescence is a method suitable for off-line studies of ink transfer in flexo.
2. X-ray fluorescence can be used to measure ink amount both on the plate and on the paper.
3. X-ray fluorescence can be used for efficient calibration of on-line methods.

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Appendix

Infra-red technology (IR)

Infrared has a wavelength just beyond the red end of the visible electromagnetic spectrum. Water has an absorption peak at a wavelength of 1.94 μm and, when water-based inks are used, it is possible to detect the amount of ink with IR. There are two possibilities of generating the IR-radiation. A halogen lamp source can be used and the white light passes through an IR filter that transmits the desired wavelength. It is possible to have a system with up to five filters so that a more precise signal can be achieved. Spectral analysis by multivariate techniques (Olsson et al, 1995) or by Fourier transforms (Backa and Brolin, 1991) can also be utilized to give even more correct measurements. The other method is to use lasers which have the desired wavelength without any filters. The advantage of lasers is that they can send light with a higher energy than the halogen lamp.

Photoacoustic technology

Photoacoustics is an optothermal experimental method that can be used to measure thickness of layers and thin films (Kaplanovà and Cerny, 1993). The method is a combination of optical spectroscopy and calorimetry and is based on the on the fact that electromagnetic radiation absorbed by a sample is converted to heat.

The photoacoustic signal is generated when a light absorbing substance is exposed to acoustically modulated incident radiation.

The light source, either a HeNe-Laser or a Xe-Lamp combined with a monochromator system is modulated by a variable speed mechanical chopper (Kaplanovà and Cerny, 1995). The modulated light generates an acoustic wave (pressure disturbance) in the gas immediately adjacent to the surface and this wave is responsible for the periodic temperature variation at the surface of the sample. The wave propagates through the volume of the gas to the microphone (detector) where a signal is produced which corresponds to the ink film thickness.

The advantage of the photoacoustic spectroscopy technique is that it is insensitive to the extrinsic parameters of the sample such as particle size and surface properties. It is also able to measure small amount of ink and can give very good results if we succeed in avoiding noise during the "transport" of the disturbance (acoustic wave) from the sample to the microphone.

Optical triangulation

The optical triangulation method is based on a distance measurement principle. The method is performed with a laser as light source, the measured surface and a lens and detector system. These three elements forms a triangle which is the reason for the name.

The collimated beam of the laser light strikes the surface of an object and the light is reflected back through a lens to a position-sensing detector. The position of the reflected light spot on the detector surface corresponds to the distance to the object.

This method can be used for measuring thickness if two conditions are respected:

1. It is necessary to have a reference, that means measuring on the plate without ink before the printing.

2. The light source must be chosen such as the reflected light comes from the surface of the sample. The light must not be able to penetrate into the ink film.

If these conditions are observed, the method has the advantage of being a direct measuring method for the thickness and, also, the results do not need to be mathematically transformed. Moreover the configuration of the system is very simple. A disadvantage is the low precision of the method because of the calibration.

Instead of using a silicon-position sensing detector, it is possible to replace it by a CCD-Camera with IR-Laser-Diode which provides a two-dimensional picture.

Another configuration can also be used. An optical measuring head images a light spot in the near infrared on the surface to be measured. This light spot is reflected by the surface and the light bundle received by the lens is imaged on optical fibers (replace the silicon detector in the precedent configuration) and led to the separate electronic unit where it is optoelectronically converted and evaluated.

Density

A conventional way of quantifying the amount of ink on the paper is by a densitometric measurement. It is possible to develop equations which permit the ink film thickness to be related to the print density. All of them have been etablished with the necessity to introduce as constants in the equation different characteristics of the ink and of the paper. The following equation (Tollenaar and Ernst, 1961) is the most adapted to water-based flexographic inks (Aspler et al, 1992; Blom and Conner, 1990).

$$D = D_\infty (1 - e^{(-my)}) \qquad (3)$$

where D_∞ is the maximum print density, m is a constant and y is the ink film thickness on the paper.

Ink consumption

Another way to achieve a value for the ink film thickness on the paper, y, is to calculate it from the ink consumption. The flexo printing unit can be seen as a box where some ink comes into the system and some ink leaves the system. A combination of equations (1) and (2) gives:

$$y = a - b \quad (4)$$

where a and b are ink amount on the the anilox roller before and after the first nip. This equation can be used if the ink release from the anilox roller is known.

If the chamber system and the paper are the limits it is possible to use another equation.

$$y = k(A - B) \quad (5)$$

where A is the ink flow into the chamber, B is the ink flow out from the chamber and k is a constant depending on the press width, the press speed and the specific weight of the ink.

The idea is then to measure the ink flow at the entrance and exit of the chamber system. The method is only useful when the print consists of full tone areas.

Conclusion (appendix)

All the methods exhibit both advantages and disadvantages. If the precision of the measurement is the most important decision factor, the IR-technique is the most accurate. Economical factors play an important role when choosing between IR-camera, NIR, FTIR and the laser technology. NIR and FTIR methods are used in the paper industry and give very good results but the investment seems to be too high. Laser technology is probably the solution of the future and to pursue the investigations in this direction appears to be a good idea (maybe in collaboration with a laser manufacturer). The IR-camera with two or more measuring heads is the best compromise between good precision and an "acceptable" investment, and offers a good tool for research.