Control of ink/water balance with the help of an on-line densitometer

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Abstract

Control of the water feed in the offset process is difficult because it is difficult to measure a thin water film with high accuracy. In this paper a method based on an indirect measurement on the print with a densitometer is described.

A method has been developed by GFL for controlling the ink - water balance. The method is based on a system consisting of an on-line densitometer connected to the water-feed system.

The principle of the method is that too low a water feed will lead to a sudden increase in half-tone print density, so that the detection of a tendency for the density in a half-tone area to increase may be used to keep the water feed above but close to the critical lower limit.

The test runs have been carried out in a laboratory web offset printing press.

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Introduction

All press manufacturers are now moving towards more and more automated presses. The importance of having a good ink and water balance is well understood, and a lot of effort is put into the adjustment of the ink feed, but the fountain solution feed is often controlled only by ensuring that the water ductor roll corresponds to the speed of the press.

This paper reports the development of a computer program which, on the basis of data from an on-line densitometer, automatically adjusts the fountain solution to the correct level throughout the printing.

Tests at VTT (1) and GFL (2) have earlier shown that it is possible to measure the water quantity indirectly by measuring the density of the print. On the basis of this finding, the present study has been carried out to determine the optimum fountain solution level via the density. A number of trial printings have been carried out in which the quantity of fountain solution has been varied, and the density, NCI-value and dot gain have been measured and studied in relation to this variation. The results obtained have supported the earlier investigations. A curvilinear relationship has been established from which it is possible to determine the optimum water quantity.

The function and influence of the fountain solution on print quality in lithographic offset printing

The function of the fountain solution is to prevent non-image surfaces on the plate from taking up ink. The ink/water balance is stable over a certain tolerance range within which the water is well emulsified into the ink. If the upper limit is exceeded, no more water can be emulsified into the ink, the tack of the ink is reduced, water marks occur in the print, the paper expands and printed pictures suffer from imperfect register. If, on the other hand, the lower limit is not reached, the water is insufficient to protect the non-image surfaces of the plate, and the result is filling-in in the dark tones and tinting. The water also contributes to keeping the rubber blanket clean.

In earlier literature, it is often stated that the optimum water quantity is the smallest possible. According to Graphometronic measurements of the dependence of the printing quality on the water quantity, this is not necessarily true (3).

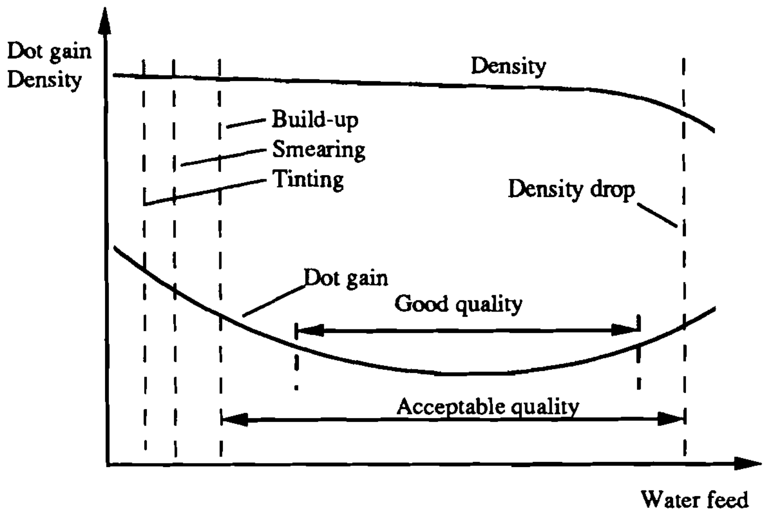


Figure 1. Principles of the relationship between full-tone density, dot gain and smearing as a function of the quantity of fountain solution according to Graphometronic (3).

The water quantity must lie above the smearing limit and also within the range which gives an acceptable dot gain. It is also best to lie above the build-up limit in order to avoid marks from dust and particles from the rubber blanket. The upper limit is set by the maximum allowable density drop. Figure 1 shows, to the left in the diagram, that at a low dampening level the lithographic properties dominate, whereas the print is affected more and more by the changes in rheology of the ink at a higher fountain solution level.

A property which is especially dependent on the water level is smearing. In the printing direction, behind a zone with a high proportion of image area, small undesirable ink dots are formed on non-image areas as the water supply decreases. The less water, the more and better visible are these undesired dots. The smearing is a consequence of the build-up of dust on the rubber blanket. According to this model , the curve of dot gain against water quantity has a minimum which corresponds to optimum printing quality.

Interaction of the fountain solution with ink

Ink and water come into contact with each other on the rolls of the press and are forced together in the roll nips. The water is not soluble in the ink since it is slightly fat. Instead, an emulsion is formed, a heterogeneous mass consisting of small water drops mixed into the ink, if the water feed is too great, there is insufficient time for all the water to emulsify or evaporate and it may then settle on the surface of the emulsion and give water marks in the print. There is a fine balance here also: If the emulsification is too strong, the tack of the ink is changed, the surface energy becomes similar to that of the fountain solution and the ink may consequently adhere to the hydrophilic surface, i.e. tinting occurs.

The hydrophobic and hydrophilic areas are not large connected areas in a screen. The image consists of many small dots of different sizes. When the water reaches the non-image surface, it spreads and prevents the ink from coming into contact with the plate. In order to obtain as good a flow as possible, alcohol and/or other additives are added to the fountain solution. The alcohol reduces the surface tension of the drops and thereby the contact angle with the plate which is hydrophilic and attracts water, so that a smaller total amount of water needs to be applied to the plate and in turn to the paper (4, 5).

The size of the tolerance area of the ink/water balance depends on a number of factors. These are of course primarily the properties of the ink, its surface chemistry and rheology, and its ability to emulsify water. The water absorption ability can be determined by the so-called Surland method, but according to FOGRA, it is not only the quantity of water which determines whether the plate remains free but also the state of the water. It is primarily the surface water which affects the lithographic process, while that which has emulsified is less important. The quantity of water required is also affected by many other factors. The surface properties of the printing plate, the porosity of the paper, surface coating and the distribution of the image on the plate can be mentioned, and also variable factors such as printing speed, temperature, the relative humidity of the air, impurities on rolls and plate and of course the composition of the fountain solution.

Methods for measurement of fountain solution feed

Several methods are available for measuring the quantity of water in the printing ink and on the hydrophilic areas of the printing plate. Examples of measurement methods are which have been tested are gloss measurement on the printing plate, IR-absorption and ultrasonics.

IR-absorption

The absorption method is based on the fact that the transmission spectra for water and offset ink are different in the infrared wavelength range. IR-radiation is directed towards the plate with its emulsified layer, is reflected there and collected by two receivers. Each channel measures the reflected radiation at a specific wavelength, one where the radiation is attenuated by the water and the other by the ink. It is thus possible to calculate how large a proportion of water there is on the plate (6, 7, 8).

Ultrasonics

A method has been developed (9) by which the ink and water quantities on the plate are determined using ultrasonics. The reflected sonic signal from the gap between two rolls in the inking device is recorded with the help of a crystal microphone and is transformed to electric signals which are subjected to a frequency analysis. From the shape of the effect spectrum, it is then possible to determine the quantity of water at the place of measurement.

Indirect densitometric measurements

Because of difficulties in e.g. calibration associated with the IR-absorption and utrasonic techniques, methods have also been developed based on an indirect assessment of the ink/water balance based on densitometric measurements.

An on-line densitometer has frequently been used for the measurement and control of the ink feed, but it has been used less often for measurement of the water.

The VTT press incorporates an on-line densitometer with which the ink/water balance has been measured and studies have shown that it should be possible to control the ink/water balance with the help of the relative contrast. At constant density, the NCI-value decreased with increasing water feed (1).

At FOGRA, the full tone density has been measured at different water levels and it has been found that the density decreases strongly when the water has been increased above a certain limit (4).

Studies at GFL

Figure 2 shows the results of preliminary studies carried out at GFL, the NCI-value being plotted as a function of the water feed (2).

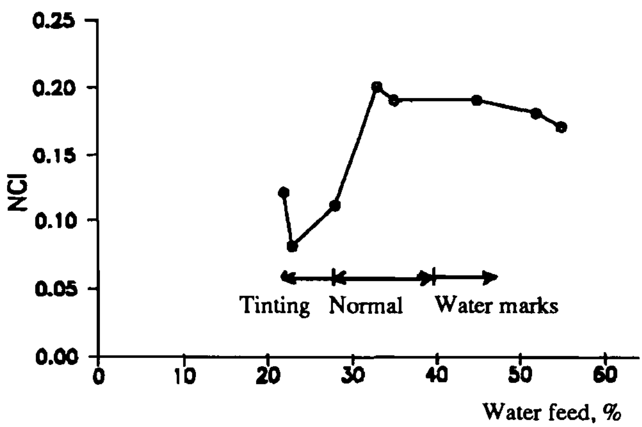


Figure 2. The NCI-value at 60% as a function of the ink feed according to GFL (2).

The lower limit for the dampening level is well defined as the point at which the curve begins to drop steeply, but the upper limit cannot be determined by measuring the NCI-value, in spite of clear water marks in the printed surface.

Further studies have now been carried out to test in greater detail the extent to which this type of measurement can be used for control purposes. The study has included a comparison of the respective merits of a simple density measurement, a measurement of dot gain or a measurement of the NCI-value. In addition, a computer program based on the measurement of the density of a selected half-tone area has been developed and evaluated.

GFL's Lito-tester

All test printings have been carried out in GFL's Lito-Tester which is a web-fed press with a maximum speed of 5 m/s. The press is equipped with two printing units which print on the same side of the paper. The printing therefore takes place with an impression cylinder and not according to the blanket-to-blanket principle. The maximum web width is 300 mm and the cut-off is 600 mm.

The printing press works with conventional rubber blankets, offset plates, inks and fountain solution.

The press is equipped with an on-line web densitometer which measures the density in a reference region on each print. The densitometer is of the broad band type with standard 45°/0° geometry. The length of the measurement area is 5 mm at a web speed of 5 m/s.

The press is equipped with an IR-dryer to dry the heat-set inks. The drying effect can be controlled manually or automatically. After the dryer, there are two cooling cylinders.

The new water-feed device on GFL's Lito-Tester

In order more easily to be able to control the fountain solution and obtain a more even dampening, the press has been equipped with a Jimek spray dampening device. Two jets distribute the fountain solution over the water ductor by spraying short doses at uniform intervals.

The dampening device can be operated either manually or automatically to vary the water feed. The fountain solution quantity is indicated as a percentage of the maximum of that which the nozzles can give.

The spray nozzle is controlled by a DC-signal, the voltage of which controls the amount of water delivered, the maximum range being 0-10 volt. In normal operation the voltage is simply related to the speed to give a proportional supply of water, but the voltage can be altered to give any desired amount of water at any given speed. The tests here reported have been carried out at constant speed.

The principle involved in using this device as a control system is thus to alter the voltage output in relation to the measured half-tone density.

Test printings: evaluation and results

A number of test printings were carried out in order to evaluate the control parameters for water adjustment using optical on-line densitometer measurement of the printed surface.

The following parameters were included in the evaluation:
- Density in 40% tone
- Density in 60% tone
- Relative printing contrast, NCI
- Dot gain.

Evaluation of density, dot gain and NCI-value

The print density is a quantitative measurement of how the eye perceives the contrast in a print. During both the repro and printing processes, however, dot gain occurs, the magnitude of the gain during printing being affected by the water, the paper, the ink and the printing conditions. The screen dots thus become larger than the dots in the original screened image and a different tone is then obtained in the print.

The dot gain in e.g. a nominal 60% area is calculated from the half-tone density D_{60}, the full-tone density D_{100} and the nominal screen area A according to the expression

$$\text{Gain} = ((1-10^{-D_{100}}) / (1-10^{-D_{60}})) - A$$

The NCI-value or relative contrast is calculated as the contrast between the full-tone density and a half-tone density (e.g. 60%) according to the expression:

$$NCI = (D_{100}-D_{60}) / D_{100}.$$

If the NCI-value is plotted against full-tone density, the curve passes through a maximum which indicates the maximum contrast achievable with this system.

Results

The investigation was designed in relation to the assumption that it would be possible to see from the density of the finished print whether or not the fountain solution was correctly adjusted. The introductory printings were carried out on 45 g/m^2 newsprint. The plate used had a high proportion of image area with a triangular zone which was expected to give early water marks. The water feed was varied from low to high and the density was measured in the 40%, 60% half-tone and full-tone areas. From the values obtained, the relative contrast and dot gain were calculated. Typical curves for these properties plotted against water feed are shown in figures 3-5.

These curves have distinctive shapes and each thus has the potential to be used for control purposes. It is not however possible to use such a curve if the property measured is dependent not only on the water quantity but also on the percentage image area on the plate. For this reason, new test printings were carried out where the proportion of image area in three regions of the plate was varied over wide limits, with measuring strips placed close to each of these areas.

Figure 6 shows that, although there is a slight difference in density level, the length of the image area has no effect on the position at which the density increases markedly with decreasing water feed. GFL's Lito Tester has no space for large paper rolls and can therefore print for only a quarter of an hour at a time, which is probably too short a time to achieve a good balance between ink and water. Another possible reason for the indefinite result was that the ink-feed screws may not have been sufficiently well adjusted to meet the requirements of the three different image areas. This technique can clearly be used for control purposes, provided values to be compared with each other are measured on the same region.

In addition to the 45 g/m^2 newsprint, two 100 g/m^2 papers, one glossy heavy coated and one matt lightly coated, were printed. In this case, the results were more difficult to interpret, especially on the heavy, coated paper.

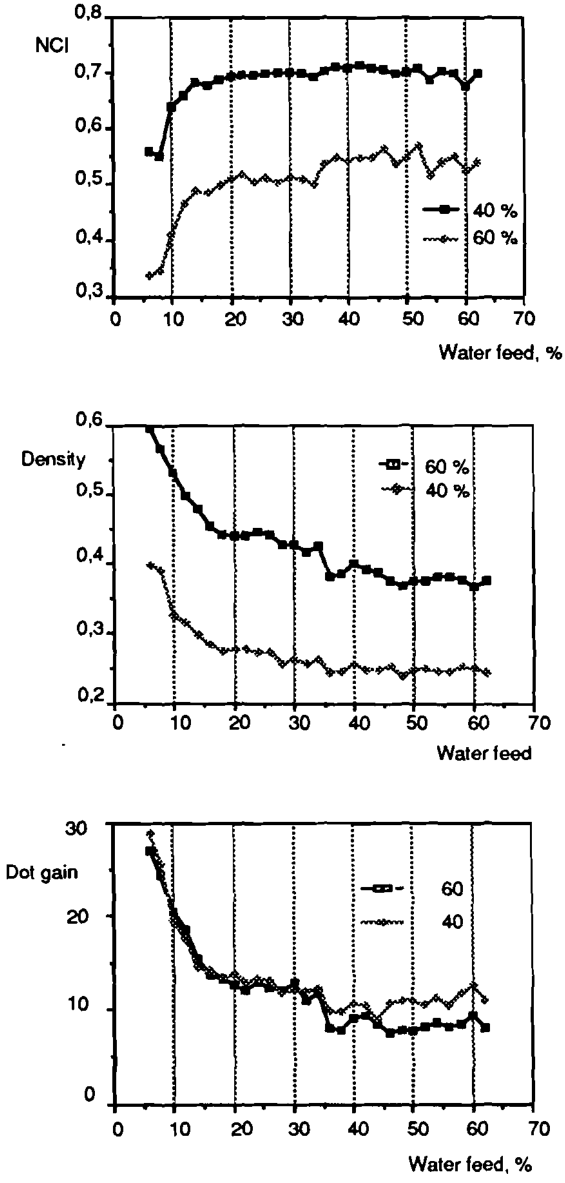
For control purposes, it is judged that the best regions to measure are the dark half-tones, where it is most clearly seen that the density decreases when the water quantity increases. The density in full tone, on the other hand, can remain constant for a long time.

Figure 3 shows the density as a function of water feed for two half-tone areas. In both cases the curve is much steeper in the low water region and a critical point can be determined at which the slope changes markedly. This is the point below which the water feed is too low. The figure shows how the curve for density can be used to determine the critical water feed.

Figure 4 shows similar data for the NCI-value and Figure 5 shows data for the total dot gain.

All three curves clearly have the potential to be used for water control.

The NCI and dot gain curves show a critical point close to that given by the density curve, but the density is easier to measure and is based on a single measurement and is therefore to be preferred.



Figures 3-5. Test printing: density, contrast and dot gain as a function of the water quantity expressed as a percentage of the maximum possible water.

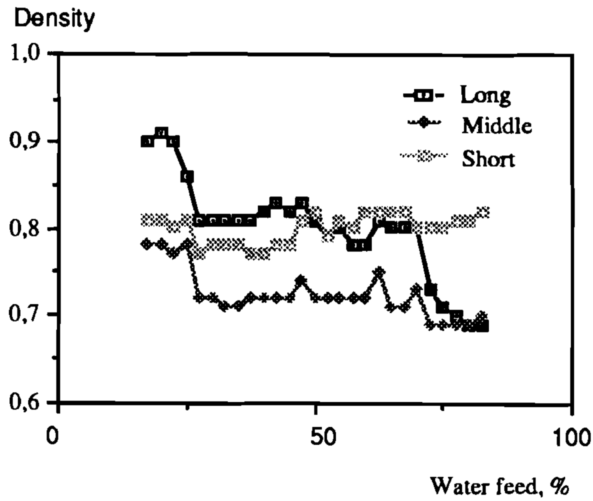


Figure 6. Test printing: influence of image-area length.

Program for control of the fountain solution on GFL's Lito Tester

The results of these measurement have been used to develop a program which automatically adjusts the water level. By measuring the density in the print and calculating the slope of the water/density curve, the program determines whether or not the water feed is correct and transmits the corresponding signal in order to control the dampening device, as shown in the block diagram in figure 7, and the flow diagram in figure 8.

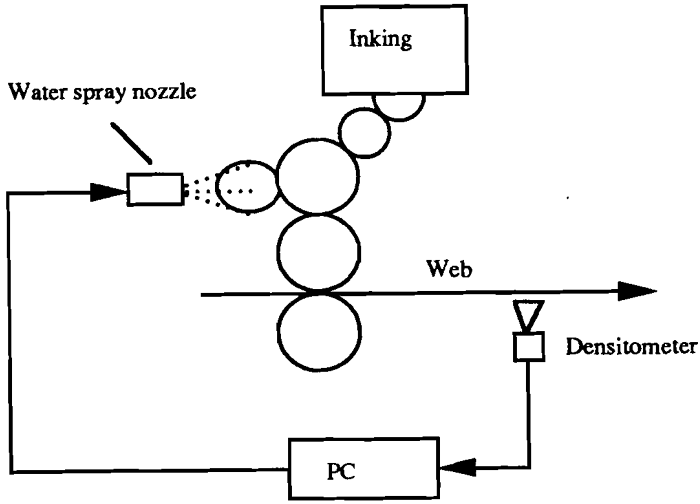


Figure 7. Block diagram over the information flow in the feedback system.

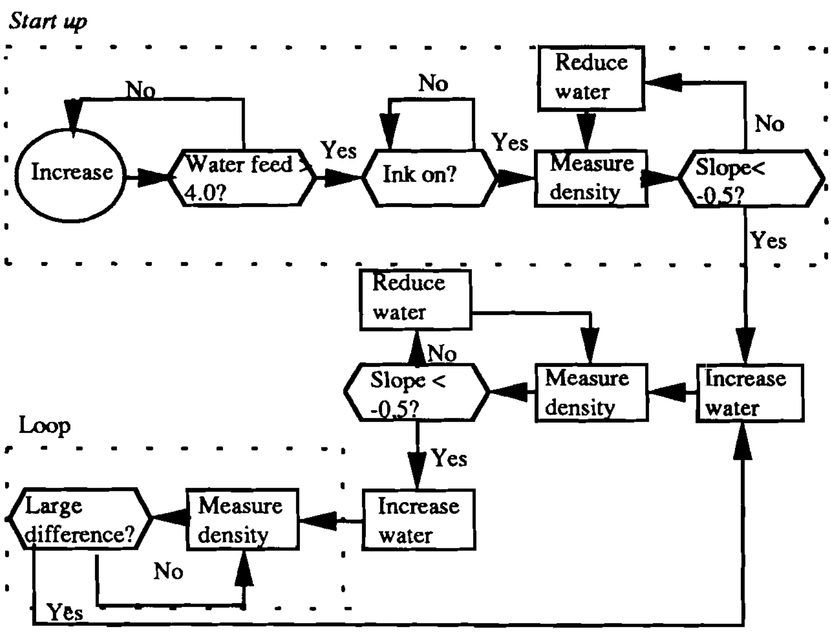


Figure 8. Flow diagram for the program.

Explanation of the operation and procedures of the program

Start-up procedure

The water quantity is allowed to rise slowly to quite a high level to dampen the plate thoroughly. When the water has reached its maximum value, the program tells the user to switch-on the ink. After it has been confirmed that the ink is switched-on, the program starts the next procedure.

Adjustment Procedure

This procedure reduces the water in large steps, until the knee on the density vs water curve is found, after which the water is increased slightly and a new step-by-step reduction takes place in smaller steps until the knee has been located more accurately. The water is then further slightly increased in order to ensure that it does not lie too close to the lower limit.

Control procedure

The water feed level is now held constant and the density is measured continuously. Average values are calculated and the difference between new and old average values is computed and compared with the standard deviation. If the difference exceeds a certain preset limit, the program asks whether any measure should be taken. The user answers "YES" or "NO". If the answer is YES, the program repeats the fine adjustment according to the adjustment procedure.

Evaluation of program Water control

The program was trial run five times at the same speed and with the same ink adjustments. The control signal to the water oscillated all the time around a value corresponding to 3.6 Volt, with a deviation of ±0.3 Volt. This means a variation of approximately 3% of the total interval of 10 volt.

Summary - Considerations for the future

Our dream is of course the fully automatic process requiring a minimum of human supervision. Without doubt, we have come part of the way: both ink and water can be controlled in different ways, we have register control and video supervision which can find tinting and other errors in the print. The problem is now: How can the ink and fountain solution be controlled at the same time? This program requires that the ink adjustment is known beforehand, e.g. by plate scanning which automatically adjusts the ink screws. This is only a coarse adjustment which must usually be done more carefully, at the same time as the water must be in the right proportion.

The suggestion made here is that a fairly high water level is chosen in the beginning, after which the precalculated coarse ink adjustment is switched-on and the water is reduced by the water control program. When a good water level has been found, the ink screws are finely adjusted with an ink adjustment program (2), after which the water is checked at the new level. The process continues with continuous measurement of the density and control of the water after each change of ink.

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