NEW, CAMERA-BASED QUALITY MEASURING METHODS FOR NEWSPAPER PRINTING

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Abstract: The research on the on-line quality measuring of newspaper printing reported at TAGA 91 has been continued. CCD camera-based, microscopic measuring of the screen dot area and systematics to relate the changes in the dot structure and quality to the variations in the ink/water balance are developed. New methods are studied to define the colour register errors directly from the printed image and an off-line measuring system is developed. The accuracy of the developed method is more than ± 0.1 mm with a suitable measuring point. A prototype project for utilizing pre-press data in the automatic colour quality inspection of the printed web is reviewed briefly

1. Introduction

The control of the offset printing process has been studied at VTT since the early 1970s. During the past five years, research has been concentrated on the measuring and control of the four-colour newspaper printing quality. The applied technology consists of electronic video cameras and image analysis. One reason is the significance of newspapers in the Finnish advertising market. Another natural reason is that the CCD camera technology is in the first stage applicable to the analysis of newspaper printing with a more restricted dynamic range. The previous results were reported at the TAGA Conferences in 1989 and 1991.

The measuring and control of the colour registers by means of separate test strips and video cameras have been solved and several reliable and cost-effective control systems are available in the market. The control of the so-called macro quality - greater quality defects - also begins to be solved by means of the sensor bars which include linear CCD cameras for detection. The measuring and control of the ink densities on a camera basis still lack reliable and cost-effective solutions. One reason is that the dynamic range of the CCD cameras has not been wide enough for the measuring of the dark tones (the densities greater than 1.0). The measuring geometry is not standard, either. Quite a few sensors would be needed in the newspaper press to reach the pagewise and, in the presses with conventional inkers, the zonewise control of the ink densities. Technically, the measurements can be made with the present technologies.

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The studies have been continued in two fields:

* the control of the ink/water balance on the basis of the changes in the structure of the printed halftone dots ;
* the measuring of the colour register directly from the printed colour image.

The present goal of our research is to develop more integrated solutions for the quality control of newspaper printing. This requires the integration of the control of several quality parameters into one system on the one hand and the integration of the quality control system into the pagemaking processes on the other hand. The last mentioned research will also be reported shortly in this paper.

2. Ink/water balance versus screen dot structure

2.1 Background

The previously made studies have shown that the structure of the printed dot changes in the function of the ink feed. An off-line image analysis station was developed for screen dot measurements already earlier. The behaviour of the printed dots in relation to the water feed was studied in this contect, by using the parameters programmed at the off-line station.

2.2 Methods

The station used included a CCD camera, a microscope, a ring light source and an image analysing unit. 16 parameters characterizing the printed dot were programmed. The samples for the analysis were partly printed at our laboratory with the Goss Community printing press, partly in the newspaper printing houses with modern 4-high-printing presses (Goss Colorliner, Koenig & Bauer - ALBERT A 510). Different water feed levels with a stable ink density were printed and analysed.

2.3 Experiments

The laboratory experiments were made with six different inks (mineral oil based, vegetable oil based and recycled inks) and with four different newsprints with the same grammage but different formation. The experiments in the printing houses were made with their normal material combinations in connection with the production runs.

The first step was the analysis of the laboratory test printings. The characteristics of the dot structure were measured in different places across the printed page and a minimum of 5 parallel samples were measured. The analysed image area consisted of 6 dots. The relation between the internal and external variation of each parameter at different measuring points was calculated to study whether the variation of the parameter could be considered statistically to result from the changes in the water feed.

2.4 Results

The parameters which are most sensitive to the changes in the water feed are shown in Table 1. The changes in the area, other area count and the void rate the printed dots in the function of the water feed are shown in Appendix 1. On the basis of the results, four new parameters were calculated. The parameter which reacted most sensitively to the water feed was selected and developed further by emphazizing the factors of the sum, using the coefficients calculated on the basis of the variation analysis.

Table 1. The results of the analysis of variances.

Mean value of the variation between the measuring points

Test series	1A	1B	2A	2B	mean
Area	10	8	9	9	**9,0**
Perimeter	7	5	7	10	**6,3**
Hole count	29	20	33	14	**27,3**
Other area count	24	27	40	44	**30,3**
Void rate	57	46	67	32	**56,7**
Blur	84	30	79	91	**64,3**
Var. of mean radius	18	9	16	24	**14,3**
Var. of square radius	28	10	16	22	**18,0**
Dot percentage	9	8	10	10	**9,0**

Mean value of the internal variation of the measuring points

Area	7	5		3	**6,0**
Perimeter	8	7		4	**7,5**
Hole count	17	15		14	**16,0**
Other area count	17	17		12	**17,0**
Void rate	25	28		24	**26,5**
Blur	42	31		40	**36,5**
Var. of mean radius	19	12		12	**15,5**
Var. of square radius	24	14		13	**19,0**
Dot percentage	5	3		2	**4,0**

The relation between variances

Area	70%	63%		33%	**66%**
Perimeter	114%	140%		40%	**127%**
Hole count	59%	75%		100%	**67%**
Other area count	71%	63%		27%	**67%**
Void rate	44%	61%		75%	**52%**
Blur	50%	103%		44%	**77%**
Var. of mean radius	106%	133%		50%	**119%**
Var. of square radius	86%	140%		59%	**113%**
Dot percentage	56%	38%		20%	**47%**

The emphazised coefficients are shown in Table 2. The equation 2 has been used to express the change in the dot structure versus the water feed. The parameters calculated with the equation 2 for the laboratory samples are shown in Appendix 2.

Table 2. Coefficients used in calculating the derived parameters

	Equation 1	Equation 2	Equation 3	Equation 4	Equation 5
Area	+1.0	+2.6	+1.0	+1.0	+1.0
Perimeter	-	-	-	-	-
Hole count	-1.0	-1.9	-	-1.0	-1.0
Other area count	+1.0	+2.6	+1.0	-	+1.0
Void rate	-1.0	-2.6	-1.0	-1.0	-1.0
Blur	+1.0	+2.2	+1.0	-	+1.0
Var. of mean radius	+1.0	+1.6	-	+1.0	-
Var. of square radius	-	-	-	-	-
Dot percentage	+1.0	+3.8	+1.0	+1.0	+1.0

Similar measurements and analyses were made for the samples gathered in the production machine tests. The changes in the area, other area count and the void rate are shown in Appendix 3. The results show that the behaviour of the parameters characterizing the structure of the printed dot does not depend mainly on the ink type, printing speed or paper type, the direction of the changes is always the same. Different parameters have also clearly noticeable changing trends.

The changes in the parameters of the production samples are not as intensive and locigal as in the laboratory samples. This may be due to the difference in the dampening process. Both production presses had spray dampening units, which keep the water consumption at a lower level. Also the construction of the printing unit was different, the new presses had 4/4 blanket-to-blanket units. We also noticed during the project that the observed parameters did not react sensitively enough to the changes in the water feed. For example, the void rate which shows the number of holes in relation to the dot area does not characterize the unevenness of the dot perfectly enough. The density deviation of the dot may be quite significant. Most of the light areas inside the dot have at least some amount of ink on the paper. The threshold value has, however, been calibrated to the paper white and these areas are excluded from the analysis. Our aim in future is to apply parameters developed for other purposes at our laboratory. The purpose is to find a method to describe the internal density deviation of the dot and to find a better correlation between the internal density deviation and the ink/water balance.

3. On-line measuring of the printed dots

3.1 Background

If we want to analyse the printed dots during the printing we have to be able to image them on-line. This was the reason why we developed an experimental system which is able to grab the image, at the production speed, in the very small area (the length of the side is 1-2 mm). It will be possible to connect the dot analysis into the system later on and to use the information for the control of the ink/water balance .

3.2 Equipment

The imaging device consists of a PC and the imaging and camera systems. The computer includes an image grabber board and a timer board. The camera system contains a separate camera head and a camera controller, for the necessary adjustments of the image signal. The imaging section comprises an objective, bellows, an optical fibre cable and an exposure disk. These parts are fastened to a bar along which the camera head moves in the cross direction. The control software takes care of the timing of the flash and image grabbing in relation to the web pulse. The system consists almost totally of standard components except for the photofibres and the exposure disk.

3.3 Development and tests

The dot area and the interesting features are very small in size. Because of the great magnification, the objective has to be quite close to the object. When the magnification is in the range from 5 to 10, the distance of the objective from the paper surface is approximately the same as the focal distance of the objective. On the other hand, for practical, mechanical reasons, it is easier to photograph the paper web from a distance. When the imaging distance is great, a longer objective and a lens with a larger diameter are needed. The optics available for microscopes was studied but no applicable objective-camera-combinations were found.

The measurements were made with an accurate colour camera. A micro-objective of a system camera was selected and fastened to the bellows frame designed for microscopic imaging. Lighting was provided by directing the flash to the paper surface through a cluster of fibres. A direct exposure with the flash does not succeed because the flash cannot be carried close enough. The flash light has to be focused on a very small area. In addition, the surface of the paper can be lighted evenly from the sides by using four clusters of fibres at an angle of 45^{O}. The fibre disk was designed and fastened to the lens cover. The edges of the clusters of fibres are near to the surface of the web. The exposure time of the flash has to be very short, because the paper web moves up to 10 μm per microsecond. One of fastest flashes, with an exposure time under 1 μs (about 0.7 μs), in the market was Palflash 500. The web has time to move only a few micrometres during the exposure.

The constructed system is shown in Figure1.

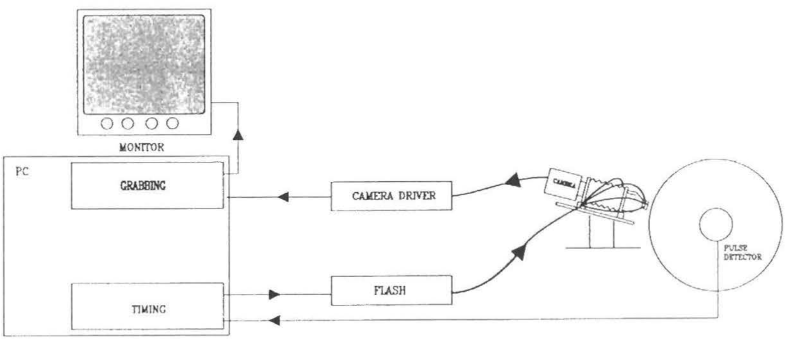

Figure 1. An experimental system for the microscopic on-line measuring of the printed dots.

The image grabbing program can take the required number of images, one after another, within a selected time range, for instance 10 pictures with a delay of 30 seconds. The images are saved on a video tape and analysed afterwards. The user can control the delay time and the saving operations.

3.4 Results

The developed system was tested both on the laboratory's test bench and in the production press during a normal production run.

The running speed of the test bench was 8 m/s. The grabbed images were recorded on the video tape. The tests were made both with coated paper and with newsprint. The grabbing of the printed dots succeeded quite well. The most important defect was the difficulty to separate the yellow dots from the newsprint paper base. This was partly due to the colour temperature of the flash which was about 7000 K.

The tests in the production environment showed that the system functions in the printing press as well. The tests did not show any problems relating to the measuring method itself which would require a special solution in the production environment.

The method can be developed further in the laboratory environment. There are two main areas which need further development:

* tbe colour temperature of tbe exposure (different light source or filters)
* the flash device (too slow for use in production runs, the time between the consecutive exposures about 10 s). It could probably be replaced by new photodiodes).

4. Control of the colour register without register marks

4.1 Background

As mentioned in the introduction several systems are available for the control of the colour register, based on the measuring of special test marks. In fact one system was developed at VTT (TAGA 89, TAGA91). The aim of this study was to find out about the possibility of measuring the colour register without any separate, visible register marks. The first step was to develop program modules making it possible to measure the colour register in the grey balance fields (used in a number of Finnish newspaper houses) or relative image areas mounted in fixed places on the page. The next step was to be able to define the register error directly in any image area of the colour picture, without any previous knowledge of the form of the image area.

4.2 Methods and equipment

On the basis of the patent survey the development of the register measurement at the screen dot level was abandoned. The activities were concentrated on the measuring of the grey balance fields or other fixed image areas and on the measurements made directly in the printed image.

The main parts of the system were as follows

* a PC-based on INTEL 486 processor and a DOS 5.0 user system
* a 3CCD matrix camera with an RGB/PAL-system

* a Zoom objective
* a lens
* an image board with a graphic and floating-point processor
* an image grabber board which produces a 768x576 / 24-bit halftone image from a PAL/RGB signal received from the camera

The software contains of programs made in C-language and the library functions of the image board. The block diagram of the softwarer is shown in Figure 2.

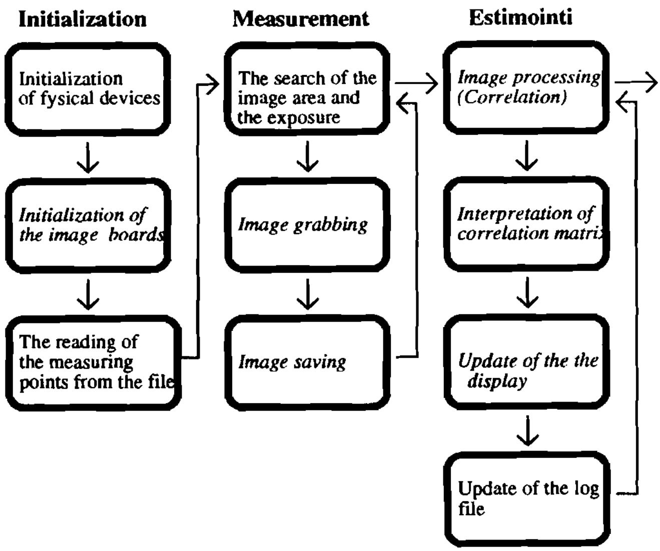

Figure 2. The block diagram of the PC-programs. The blocks with the italic fonts include instructions for the image board.

The main steps of the register measuring were as follows

* image grabbing and transformation RGB -> CMY
* an estimation of the register error of the different colours in pairs by means of a correlation algorithm; the correlation is calculated by the Fourier transform.
* an estimation of the register error by means of the correlation matrix

RGB-CMYK transformation

The tone values of the grabbed RGB image can be transformed into a CMY form by inverting. The purity rate of the printing inks is not compatible with the ideal CMY colours. That is why the relative amounts of the individual inks have to be changed by means of the linear matrix conversion.

The four-colour approximation of the printed picture is processed by subtracting the black portion from the CMY image.

The problem is that some of the CMY grey composed of the coloured inks is subtracted, too. Only one part of the CMY colours are seen in the CMYK colour separation and the black component K includes some CMY grey in addition to the real black ink.

4.3 Experiments

The method has been tested by measuring the grey balance test field and fields directly in the colour image of four-colour test pages. The RGB-CMYK transform parameters were derived iteratively from the test material. The register error was measured in pairs for cyan and magenta, and magenta and yellow. The register error between cyan and yellow was calculated on the basis of the obtained values. The actual register error was defined with the nonius scales mounted on the page. The accuracy of the developed method was defined as a difference between these two measurements.

4.4 Results

The results from three different measuring points are shown in Appendices 4.1-4.3 and the measuring points in Appendix 5. The accuracy of the developed method is more than ±0.1 mm. This, however, requires selection of a suitable measuring point. The accuracy of the method can be improved by using a higher resolution, but then the dynamic range decreases relatively and the requirements for the picture content increase.

The measuring area suitable for the measurement contains all the three coloured inks but as little black as possible. The density variations in the measuring area have to be abrupt enough, which means that the gradients have to be suffiently strong for every colour both in the vertical and in the horizontal direction. The peak values of the gradients have to be one upon the other. The grey areas with high contrasts have these characteristics in practice. The position of the black colour has to be defined using a separate measuring point.

The screen dots cause a regular noise which disturbs the measurements. The noise can be eliminated by filtering the frequency that results from the mutual distance of the screen dots from the picture. Because of the different screen angles the distance is a function of the direction and the examined ink. The difference caused by the direction is different wish different inks and this broadens the spectrum of disturbances. The size of the screen dot affects the frequencies, deviating from the main frequency. Filtering causes a loss of information, which affects the measuring results, especially when the register error is equivalent to the distance of the screen dots or its multiple.

At this stage, the method requires a grey balance field which is permanently mounted on the page. Another possibility is to define the measuring points in advance, by analysing the product during the prepress phase and by sending this information to the control system. The register of the black ink has to be defined separately in both cases. This is an off-line method, yet the speed can be increased significantly.

5. Other developments

A prototype for utilizing pre-press data in the automatic colour quality inspection of the printed web is presently under development. The inspection is performed by a movable colour CCD-camera that images the web under stroboscopic light. The measurement locations and goal values are determined from the PostScript description of the digital page. A set of criteria is used to find the best suited spots for the measurements. In addition to providing data for the on-line control, the page analysis estimates the ink consumption of the printing press as a base for presetting the ink feed.

6. Conclusions

The paper above consisted of three parts

1. The studies of the dot structure in the function of the ink/water balance

2. The microscopic on-line measuring of the screen dots

3. The off-line measuring of the colour register in the image area

The results show that the dot structure reacts to the changes in the ink/water balance. However, the parameters based on the image analysis used in this context are not sensitive enough to characterize the changes in the dot structure unequivocally enough. New parameters developed for certain measurements of the paper structure will be applied this year. The measuring of the print on the dot level has been tested and found to be possible. Further development will be needed, relating to the exposure and a better separation of the yellow ink. An off-line method has been developed for measuring the colour register directly in the image area. The accuracy of the method is better than ± 0.1, with suitable measuring fields. The data on suitable measuring points in the picture areas could be defined in the prepress processes. Also a correlation model for every ink could be defined in the prepress phase. The register of the black ink has to be defined separately. The method could be developed further for commercial use.

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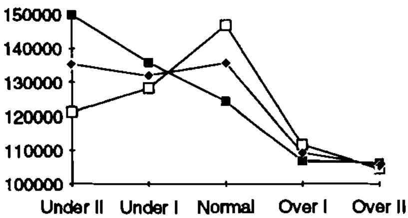
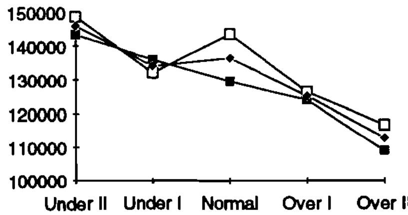
The change of the dot area in the function of the water feed

Pine



Rape-seed A4



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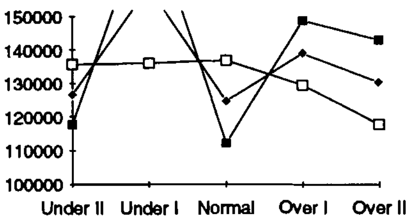
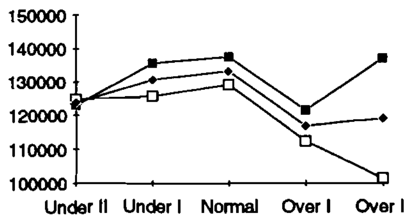


Mineral



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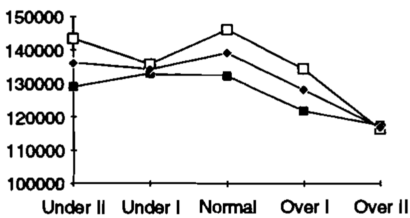
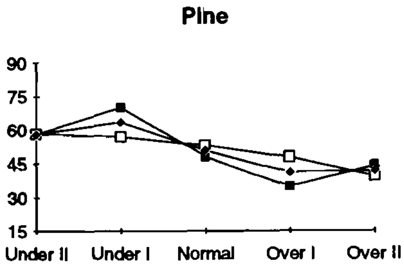
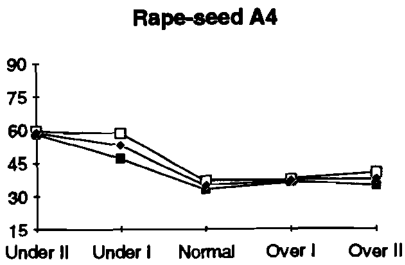
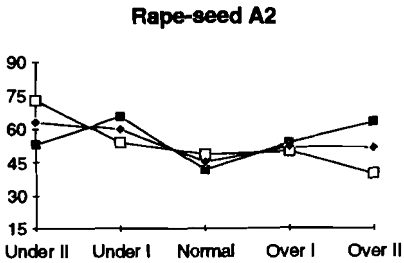


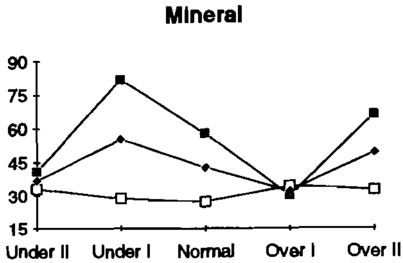
Printing with 5 different colours at the speed of 16000 rph

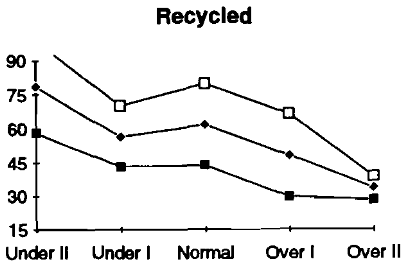
Other area count in the function of the water feed







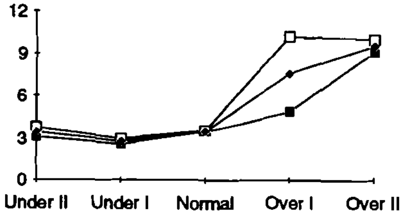




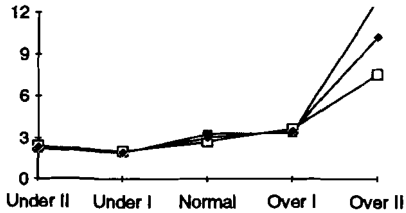
Printing with 5 different colours at the speed of 16000 rph

Void rate in the function of the water feed

Pine



Rape-seed A4



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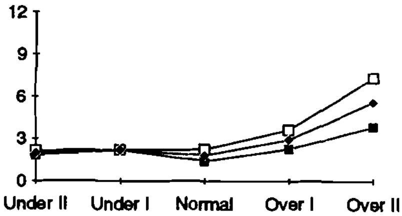
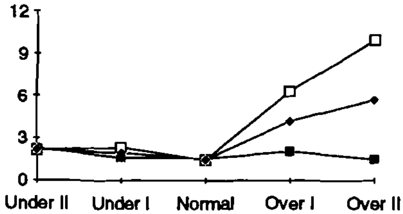


Mineral



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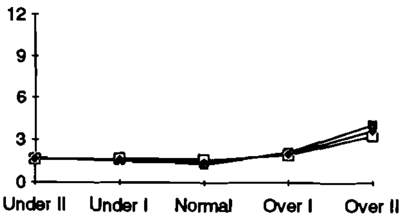
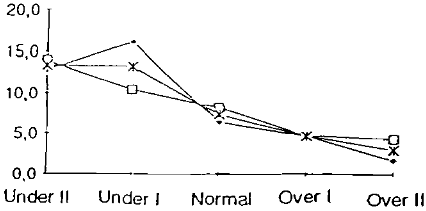


Printing with 5 different colours at the speed of 16000 rph

The results of the equation 2 in the function of the water feed

Pine



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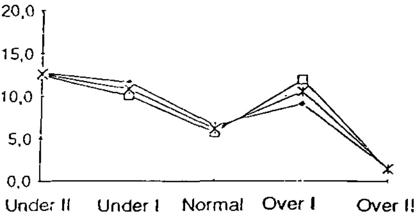

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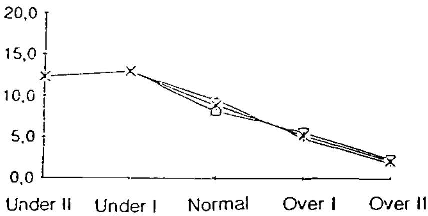
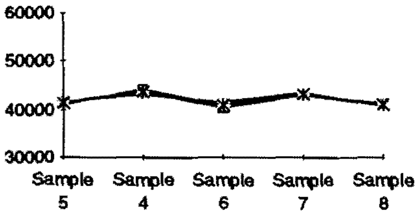


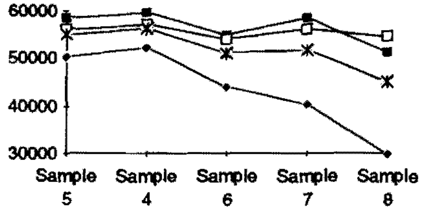
Examples of 3 different inks

The change of the dot area in the function of the water feed

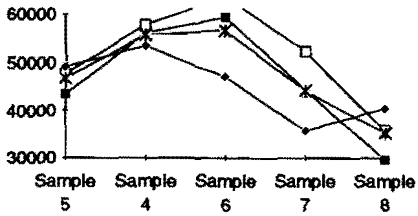
Black



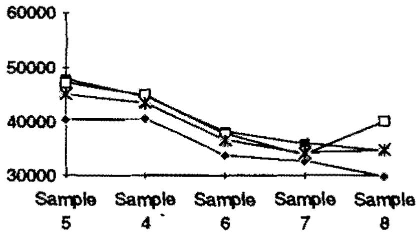
Magenta



Cyan

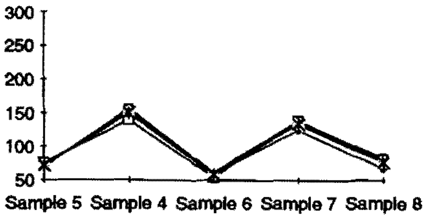


Yellow

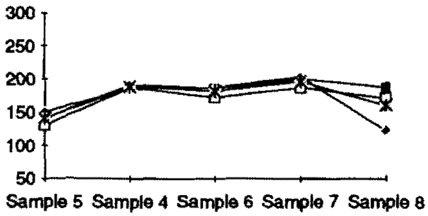


Other area count in the function of the water feed

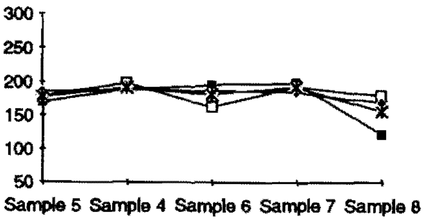
Black



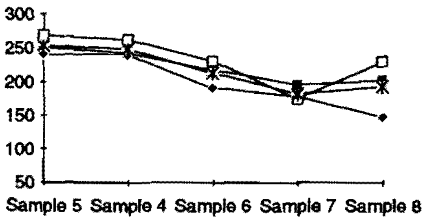
Magenta



Cyan

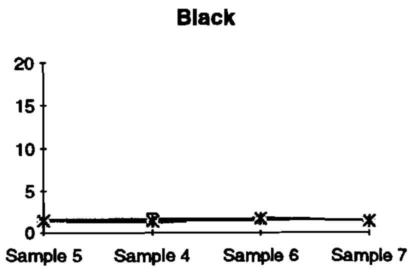


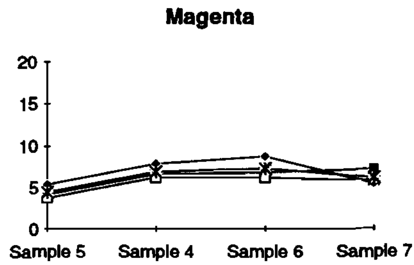
Yellow

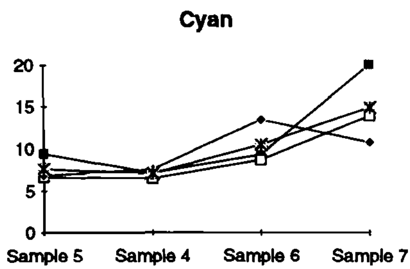


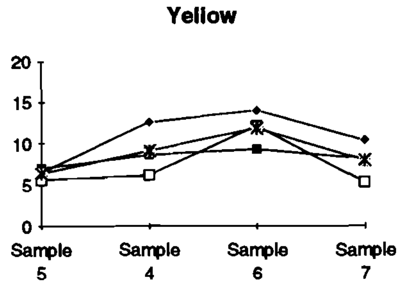
Production test runs

Void rate in the function of the water feed

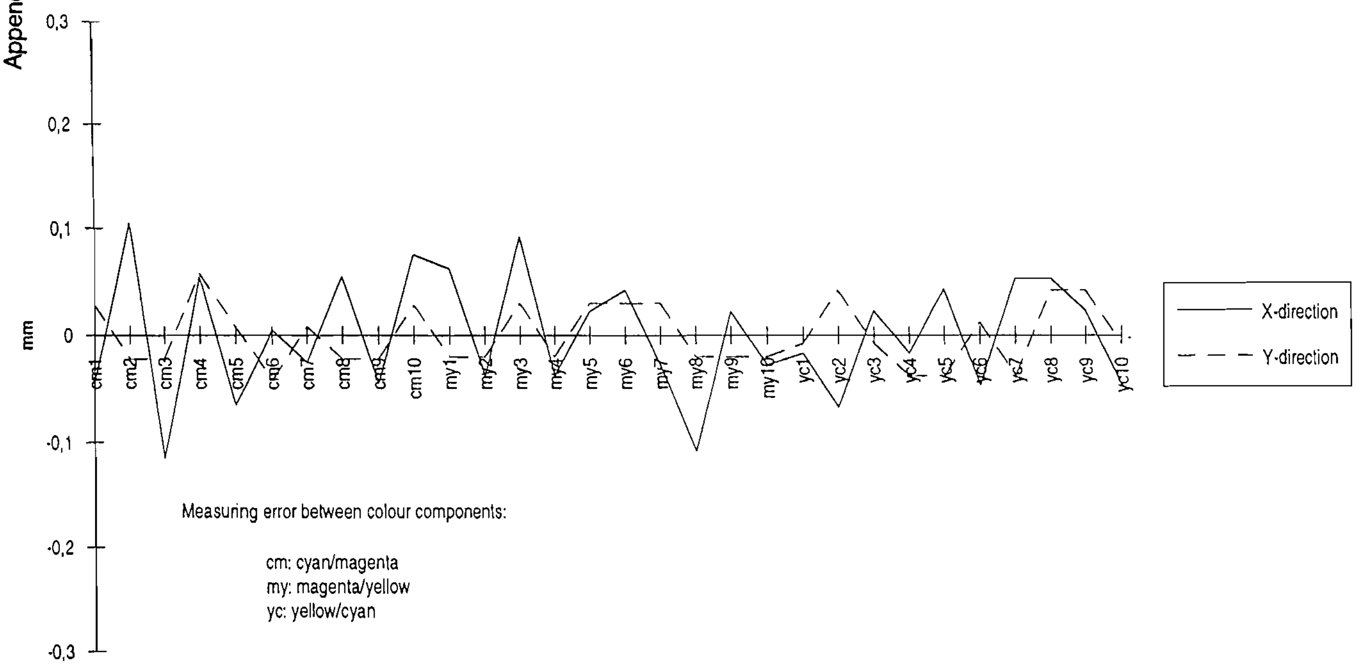




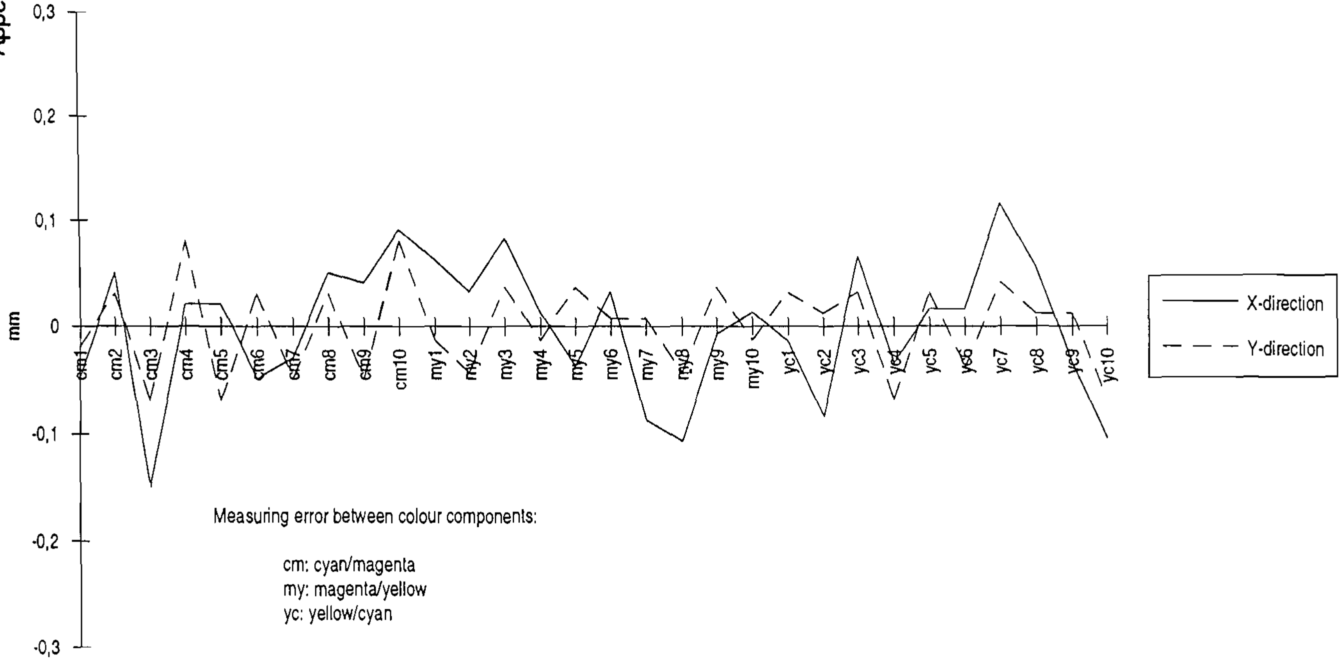




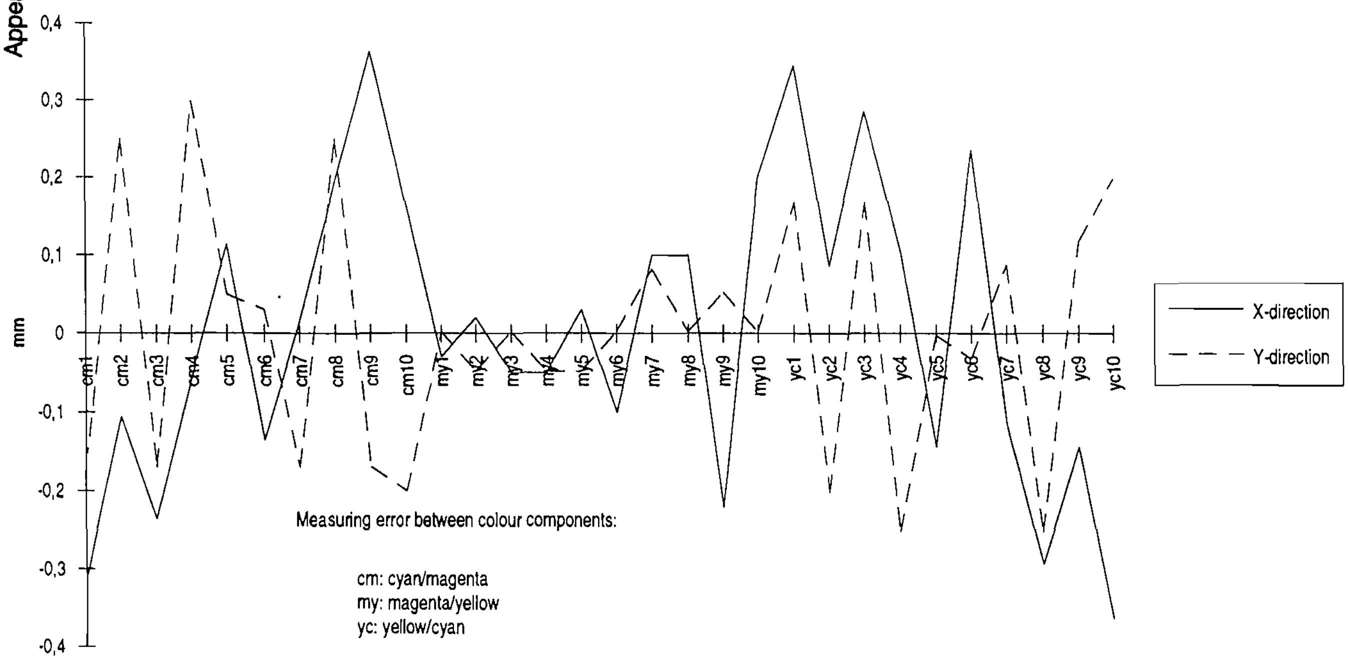
Measuring error: point 1 / sheets 1...10



Measuring error: point 2 / sheets 1...10

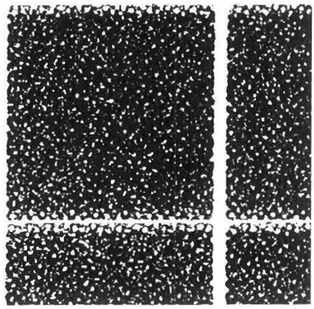


Measuring error: point 3 / sheets 1...10

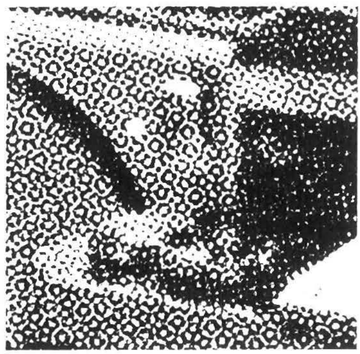


The examples of the measuring points for the colour register measurement

Point 1



Point 2



Point 3