An Alternative Method to Determine Register Variation by Using a Spectrophotometry Tool

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Abstract

The measuring of register variation is very important for putting in operation or repair and service of a multicolor press. The print machine manufacturers also need the evaluation of register variation for research and development of new products. The commonly used method for measuring register variation is based on image processing. This method is very accurate but also exclusive. Most of the consulters of the graphic industry cannot afford such a technology. This paper introduces an alternative method, whose results are close to the results of an image processing method for measuring register variation. The proposed method is based on spectrometry and colorimetric and is not so expensive compared to the image processing method. In this paper we describe how the proposed method works.

Introduction

In a multicolor press the transportation of the printing substrate from one printing unit to the other one must be very precise. An imprecise transportation of the printing substrate causes register variation. Register variation is a displacement of the printing detail from sheet to sheet. The amount of displacement is different by every sheet. Due to the wet in wet printing (i.e., offset printing) register variation causes doubling. Doubling in a multicolor press will cause visible color variation. Reducing of register variation in a press is the biggest task and challenge for every print machine manufacturer (Hauck, 2007a to 2007f). However a zero tolerance of register variation of

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printing substrate is impossible due to technical circumstances (i.e., high printing speed, instability of proportions of substrate within the printing process). In the multicolor printing it is more important that the amount of register variation is within defined and acceptable tolerances. The range of register variation is described in (bvdm, 2002). In this paper we first give a short background of the problem and the existing models, later we describe our proposed model and finally we present the results of the proposed method.

State of the Art

Today two methods are used for measuring dynamic register variation or doubling. One of them (slur and doubling evaluation according to the FOGRA method) is based on measuring the fractional area. The FOGRA method is based on the comparison of fractional area of the horizontal and vertical single color printed lines (figure 1a). The FOGRA method is not a method of measuring register variation directly; it just measures the effect of register variation (doubling value). The second method is the determination of register variations by image processing technique. Usually SID-Luchs equipment is used for the image processing method (figure 1b). In the following the two methods mentioned above will be explained briefly.

FOGRA/bvdm method: This is an easy method for printers to measure and evaluate slurring and doubling (FOGRA, 2005). By using this method 25 sheets will be evaluated according to equations 1 to 4.

In equation 1 VP denotes the density of the vertical line patch. HP in equation 1 denotes the density of the horizontal line patch. $\mathbf{X_i^A}$ denotes the comparison of fractional area of the horizontal and vertical patches. In equation 2 $\overline{\mathbf{X_{SD}}}$ is the arithmetic average of $\mathbf{X_i^A}$, $\mathbf{s_{SD}}$ in equation 3 is the standard deviation of $\mathbf{X_i^A}$, $\mathbf{SD}$ in equation 4 is the sum of $\overline{\mathbf{X_{SD}}}$ and $\mathbf{S_{SD}}$ and the slurring and doubling value according to FOGRA (figure 1-a).

$$\mathbf{X_i^A = abs\left|\frac{1-10^{-VP}}{1-10^{-solid}} - \frac{1-10^{-HP}}{1-10^{-solid}}\right|} \qquad (1)$$

$$\overline{\mathbf{X_{SD}}} = \sum_{i=1}^{25} \frac{\mathbf{x_i^A}}{25} \qquad (2)$$

$$s_{SD} = \sqrt[2]{\frac{1}{24}\sum_{i=1}^{25}\left(x_i^A - \bar{x}\right)^2} \tag{3}$$

$$SD = \overline{x_{SD}} + s_{SD} = \sum_{i=1}^{25}\frac{x_i^A}{25} + \sqrt[2]{\frac{1}{24}\sum_{i=1}^{25}(x_i^A - \bar{x})^2} \tag{4}$$

One of the biggest difficulties of this method is that the accuracy of most of the CTP-systems is not high enough to expose absolutely exact horizontal and vertical line patches. But it is most important for equation 1 that vertical (VP) and horizontal lines (HP) have absolutely the same fractional area on the printing plate. Otherwise by calculating X^A one will not know if the difference value is due to the influencing factors of printing process (register variation) or if it is caused by an imprecise imaging of CTP. Another problem of such an evaluation is if we have horizontal and vertical register variation with the similar amount of register variation for VP and HP the X^A will be zero or very close to zero. In that case we will not have an adequate value for register variation. The other big difficulty is that the result is only percentage and not metric. The result just describes if the slurring and doubling value is maintainable or not. There is no possibility to use this method to draw a meaningful graphic of register variation from one printing unit to another unit. But that is absolutely necessary for putting in operation or repairing a press.

SID-Luchs method: For measuring register variation from sheet to sheet and in order to draw a meaningful graphic of register variation an image processing technology is usually required. One of the most popular systems for this aim is the SID-Luchs system, an almost industrial standard for print machine manufactures. This system is able to evaluate register variation by drawing its graphics. It determines metric values (figure 1-b).

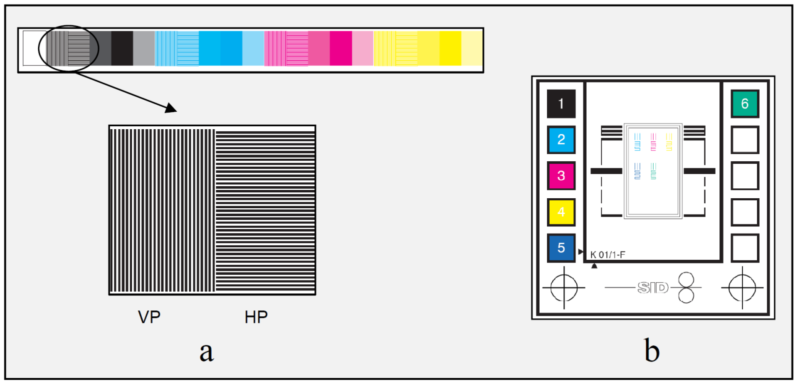

Figure 1. a: PQS-I Strip. (PQS: Print Quality Standard).
The density of VP and HP (zoomed) will be used in equation (1).
b: SID-Luchs measuring element.

Range of tolerance for register variation: The tolerance and parameters of register variation are given in (bvdm, 2002). The standard deviations of all registers shifting have to be less than 10 µm (for a 4-color offset printing machine). For a printing machine with more than four print units 1.5µm/unit has to be added to the 10µm for the horizontal and 1µm/unit to the 10µm for the vertical register shifting.

Goal

Determination of register variation: Now the target is to investigate a method "not based on image processing" that achieves more accurate and usable result than the bvdm/FOGRA method for evaluation of register variation. In the following a model will be proposed that allows the evaluation of register variation by using "only a spectrometer device" but the result is "almost a metric value". By using this method it is possible to draw the meaningful graphics of register variation in order to put a press in operation or to repair it.

Model

The model here is based on partly overlapped micro lines and gaps. The corresponding lines are printed in two different printing units (figure 2). The register variation will be measured either between two consecutive printing units (i.e., PU (printing unit)-2 and PU-3) or between two printing units as a section (i.e., PU-1 and PU-4). At first the basis lines of the basis printing unit (i.e., cyan) and afterwards the reference lines of the reference printing unit will be printed.

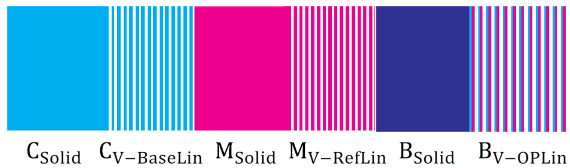

Figure 2. The measuring strip for the proposed model for measuring register variation between PU-2 (i.e., cyan) and PU-3 (i.e., magenta).

In the following it is assumed that the register of reference printing unit (i.e., magenta) is constant and that there are register variations at based printed micro lines (i.e., cyan). Assuming that while the printing of consecutive sheets there will be a sidewise register variation of cyan and partly overprinting of magenta (i.e., of $B_{V-OPLin}$ -patch in figure 2). So we will have varying amounts of width of cyan lines, blue (overprinted) lines, magenta lines and unprinted white gaps from sheet to sheet. Of course the width of these lines also corresponds to their fractional area. The variation of width of these lines is depending on the sidewise register variation from sheet to sheet (figure 3). Now if we succeed to define each fractional area and the width of the lines (cyan, blue, magenta, and white) and determine the amount of varying of the lines width from every sheet to another consecutive printing sheet, we will also be close to define the register variation.

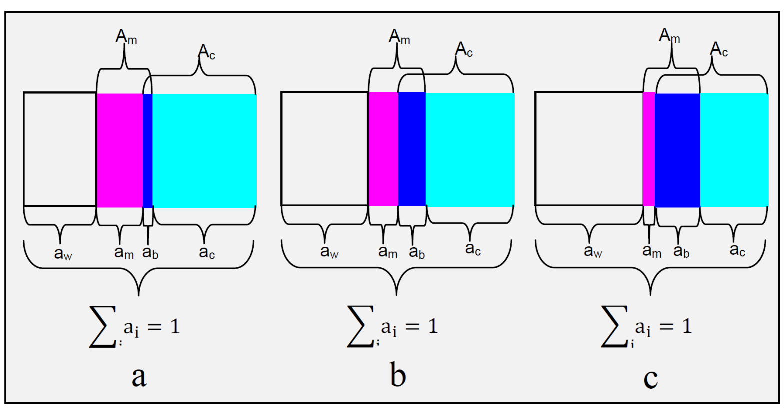

Figure 3. b: demonstrates a printed sheet, i.e., with normal sidewise register portion between print unit-2 (cyan) and print unit-3 (magenta). Figure b and c demonstrate register shifting in two different directions.

Let us now concentrate on the vertical lines for the sidewise register variation. For better explanation we only regard one of these lines and unprinted gaps. As shown in figure 2 for the creation of a measuring strip it is necessary to set the basis and reference line. The basis line (figure 4 a, i.e., cyan) is of the same width as the unprinted gap (area coverage 0.5 or 50% in prepress file).

$$\textbf{Basis line} + \textbf{its unprinted gap} = 1$$
$$\textbf{Basis line} = \textbf{its unprinted gap} = 0.5$$

For the width of reference line (figure 4 b, i.e., magenta) we choose the 1/4 width of basis line plus unprinted gap. The area coverage of reference line is 0.25 or 25% in prepress file.

$$\textbf{Reference line} + \textbf{its unprinted gap} = 1$$

$$\textbf{Reference line} = 0.25; \ \textbf{its unprinted gap} = 0.75$$

$$\textbf{Reference line} = 0.25\,(\textbf{Basis line} + \textbf{its unprinted gap})$$

If a partly overlapped printing takes place the result will appear similar to the illustration (figure 4 c).

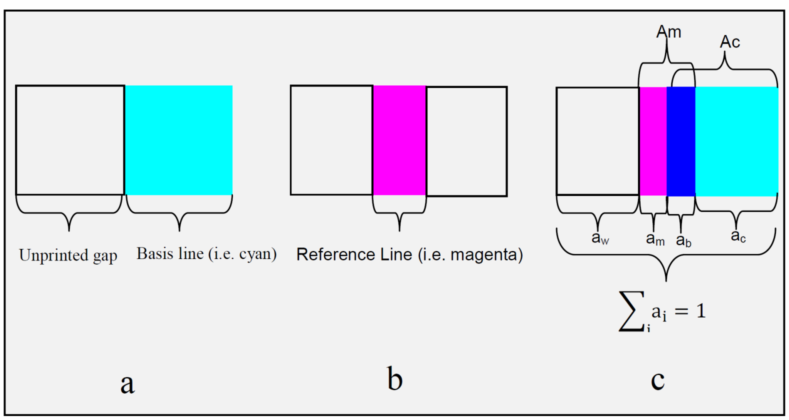

Figure 4. a: For better explanation only one of the lines of the $C_{V-BaseLin}$ *patch (figure 2) is here demonstrated. b: Zoom of one of the reference lines* $M_{V-RefLin}$. *c: Zoom of one of the partly overlapped lines of the* $B_{V-OPLin}$. *Partly overlapped (blue area) of reference line (i.e., magenta) onto the basis line (i.e., cyan) is here demonstrated.*

Here a_c is the fractional area of cyan, a_b the fractional overprinting area of cyan and magenta (resulting in = blue), a_m the fractional area of magenta, and a_w the unprinted area. But the A_c is the tone value of printed basis line (determined by using of, $C_{V-BaseLin}$ patch in figure 2). That means the coverage area in prepress data plus dot gain in print. We assume that the $A`_c$ in $C_{V-BaseLin}$ corresponds to A_c in that patch (i.e. $B_{V-OPLin}$). Like A_c, A_m is the tone value of printed reference line (in our sample printed with magenta, $M_{V-BaseLin}$ in figure 2). Therefore the A_m is the coverage area in data plus dot gain in print also.

To define the fractional area, the Neugebauer equation has to be used. Please note that the Demichel´s dot over lap model is based on random of dots (assumes that the color dots are printed independently (Gooran, 2001)) and therefore cannot be used here.

As mentioned before the register variation from sheet to sheet corresponds to variation of width of lines and their fractional area. Hence to define the register variation between the cyan printing unit and magenta it is necessary to define the variation of the amount of fractional area of magenta a_m.

Equations

According to figure 6: $\sum_i a_i = 1$ (5)

$$a_w = 1 - (a_c + a_b + a_m) = 1 - A_c - a_m \quad (6)$$
$$A_c = a_c + a_b \quad (7)$$

$$a_w = 1 - (a_c + a_b + a_m) = 1 - A_m - a_c \quad (8)$$
$$A_m = a_m + a_b \quad (9)$$

According to equation 7 => $a_c = A_c - a_b$ (10)
According to equation 9 => $a_m = A_m - a_b$ (11)
According to equation 6 and 9 => $a_w = 1 - A_c - A_m + a_b$ (12)
The a_b and a_m are unknown.

Please notice again that due to printing and register variation and dot gain the width of the cyan and the magenta lines differ compared to their width in prepress data, i.e. $A_m \neq 0.5$, $A_c \neq 0.25$, and $a_w \neq 0.25$! Therefore the printed A_c and A_m here have to be calculated as following. First we introduce two new variables Ec and Em. The width of $A`_c$ and $A`_m$ is to be determined by $C_{V-BaseLin}$ and $M_{V-RefLin}$ (figure 2 and 5). We assume that

$A`_c$ and $A`_m$ are determined by $C_{V-BaseLin}$ and $M_{V-RefLin}$ correlate to A_c and A_m from $B_{V-OPLin}$ patch (figure 2 and 5). Nevertheless there is a small difference between A_m and A_m and between $A`_c$ and $A`_c$. Thus, E_c in equation 13 denotes the error of the measuring result between A_c and $A`_c$ . $E_m$ in equation 14 denotes the error of the measuring result between $A_m$ and between $A`_m$.

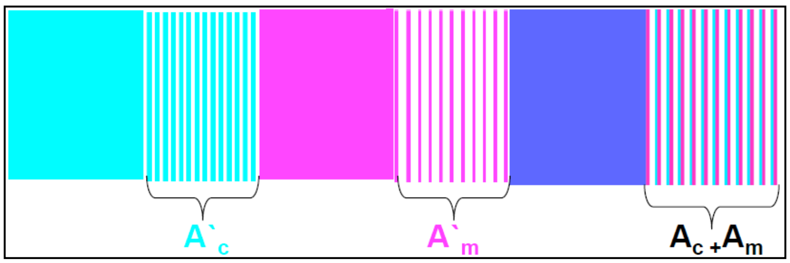

Figure 5 Here is assumed that the width of $A`_c$ and $A`_m$ determined by $C_{V-BaseLin}$ and $M_{V-RefLin}$ correlate to the width of A_c and A_m from $B_{V-OPLin}$ patch.

$$\mathbf{A_c = A`_c . E_c} \tag{13}$$

$$\mathbf{A_m = A`_m . E_m} \tag{14}$$

According to the Murray Davis equation:

$$\mathbf{A`_i = \frac{[X+Y+Z]_w - [X+Y+Z]_{i`}^{screen}}{[X+Y+Z]_w - [X+Y+Z]_i^{solid}}} \tag{15}$$

X,Y,Z denote the three stimulus values. The Murray Davis equation (equation15) is here solved as an energetic one. Therefore the sum of three stimulus value is to be set in equation 15. One of the advantages is that it is easier and more practicable to set the same value and signal (three stimulus values) for equation 15 like for equation 20 and equation 22. $A`_i$ denotes the fractional area of base line (i.e., cyan) or reference line (i.e., magenta) after printing

According to Neugebauer equation:

$$\mathbf{\begin{matrix} X_t \\ Y_t \\ Z_t \end{matrix} = \sum_i a_i . \begin{matrix} X_i \\ Y_i \\ Z_i \end{matrix} \qquad \sum_i a_i = 1} \tag{16}$$

The equations 10 to 15 result in the equation system (17).

$$X_t = (E_c \cdot A`_c - a_b).X_c + (E_m.A`_m - a_b).X_m + (a_b).X_b + (1 - E_c.A`_c - E_m.A`_m + a_b).X_w \quad Y_t = (E_c.A`_c - a_b). \tag{17}$$

The tristimulus values XYZ of equation 17 result from different measuring patches. The index "$_c$" denotes the values of the solid cyan (C_{Solid}), "$_m$" the magenta (M_{Solid}), "$_b$" the blue (B_{Solid}), "$_w$" the printing substrate, and "$_t$" then values of the line screened printed blue patch ($B_{V-OPLin}$).

Equation 17 can now be rewritten as:

$$\begin{bmatrix} (X_b + X_w - X_c - X_m) & A`_c.(X_c - X_w) & A`_m.(X_m - X_w) \\ (Y_b + Y_w - Y_c - Y_m) & A`_c.(Y_c - Y_w) & A`_m.(Y_m - Y_w) \\ (Z_b + Z_w - Z_c - Z_m) & A`_c.(Z_c - Z_w) & A`_m.(Z_m - Z_w) \end{bmatrix}^{-1} . \begin{bmatrix} (X_t - X_w) \\ (Y)_t - X_w) \\ (Z_t - X_w) \end{bmatrix} = \begin{bmatrix} a_b \\ E_c \\ E_m \end{bmatrix} \tag{18}$$

Now the result of the equation 18 is the amount of the fractional area of blue a_b. As mentioned before, there is a small difference between A_m and A_m and between $A`_c$ and $A`_c$. Hence the equation 20 should give a value about 1 for E_c and E_m.

The amount of the fractional area of magenta a_m is given by:

$$\mathbf{a_m = A_m - a_b} \tag{19}$$

The A_m error between the $A`_m$ in $M_{V-BaseLin}$ (figure 2 and 5) and the corresponding $A_m$ from $B_{V-OPLin}$ (figure 2 and 5) has to be compensated. Therefore $E_m$ in equation 18 will be multiplied with $A`_m$ in equation 20 to get a better result of a_m. $A`_m$ is determined in equation 15.

$$\mathbf{a_m = (A`_m . E_m) - a_b} \tag{20}$$

Notice that here a_c is the fractional area of cyan, a_b the fractional overprinting area of cyan and magenta (= blue), a_m the fractional area of magenta, and a_w the unprinted area (figure 3c). $A`_c$ is the tone value of printed basis line (in our sample determined by using of, $C_{V-BaseLin}$ patch in figure 2). That means the coverage area in data plus dot gain in print. We assume that the $A`_c$ in $C_{V-BaseLin}$ corresponds to A_c in ($B_{V-OPLin-L}$). $A`_m$ is the tone value of printed reference line (in our sample printed with magenta, $M_{V-BaseLin}$ in figure 2). We also assume that $A`_m$ in $M_{V-BaseLin}$ corresponds to A_m in ($B_{V-OPLin-L}$). According to the amount of register variations by printed samples, the amounts (the fractional area and the width) of a_m vary also. After calculating of a_m for every (consecutive) printed sheet the evaluation of register variations can begin.

Evaluation of Register Variation

For the evaluation of register variation more consecutive printed sheets are needed. The number of the evaluated sheet $\mathbf{u}$ is dependent on the distribution of the register variation values. A thumb of rule is to evaluate a series of 50 consecutive printed sheets. Assuming that we have a series of measured data of a_m with $\mathbf{u}$ data of the fractional area a_m. For the further equations we will use the general form of register position a_i.

$$\bar{\mathbf{a}} = \frac{\mathbf{1}}{\mathbf{u}} \sum_{\mathbf{i}=\mathbf{1}}^{\mathbf{u}} \mathbf{a}_{\mathbf{i}} \qquad (21)$$

$\bar{\mathbf{a}}$ is the arithmetic average of a_i.
a_i is in our sample equal to a_{mi}

In equation 22 c_i is the centered and metric transformed value of a_m from equation 20. For the centering of a_i, each a_i has to be subtracted from $\bar{a}$ in equation 21.

$$\mathbf{c}_{\mathbf{i}} = (\mathbf{a}_{\mathbf{i}} - \bar{\mathbf{a}}).\,\boldsymbol{\delta} \qquad (22)$$

The value a_i has to be centered and metrically scaled. The factor δ will be used to transform the centered fraction area amount to a metric amount. In this example a single basis line is x = 128[µm] wide. As mentioned before we had 0.5 in data for the fractional area of basis line (figure 4a). That means the scaling amount is $\delta[\mathbf{\mu}m] = \mathbf{2}x = 25\mathbf{4\mu}m$. Now the factor δ converted the fractional area (i.e., a_m) to a metric unit. For example, if we have $a_m = 0.35$ for the sheet no. 1 and $a_m = 0.5$ for the consecutive printed sheet (no 2) than we will have a movement = 0.15. In our sample the amount of δ is = 254µm. We also get 254µm*0.15 = 38.1µm register movement between the first and second sheet.

Results

Afterwards the SID value should be compared to the alternative method and the difference should be determined. In the following the graphic and the numerical results of SID-Luchs device and the new method are demonstrated. The achieved result looks good. For testing and comparing both methods it was necessary to have samples with a high dynamic of register variations.

Hence the samples were produced under following printing conditions: The press was accelerated from minimum printing speed to the maximum speed with open driver shaft. Please don’t simulate that at your press. Otherwise you can damage your press!

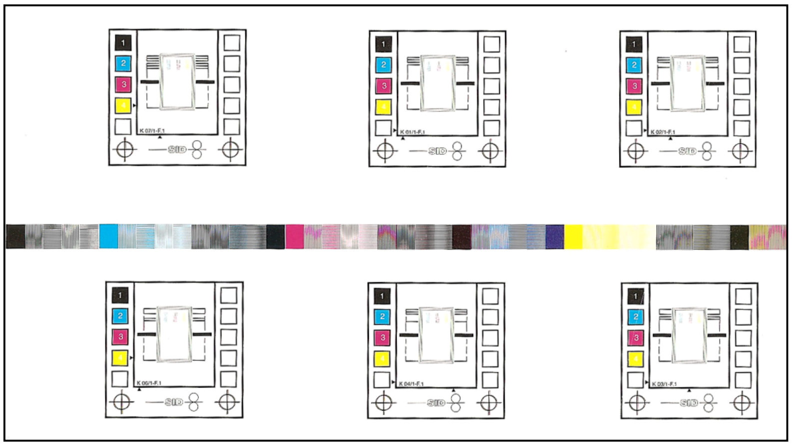

Figure 6. The six SID elements for the comparisson of both methods are placed around the register variation strip.

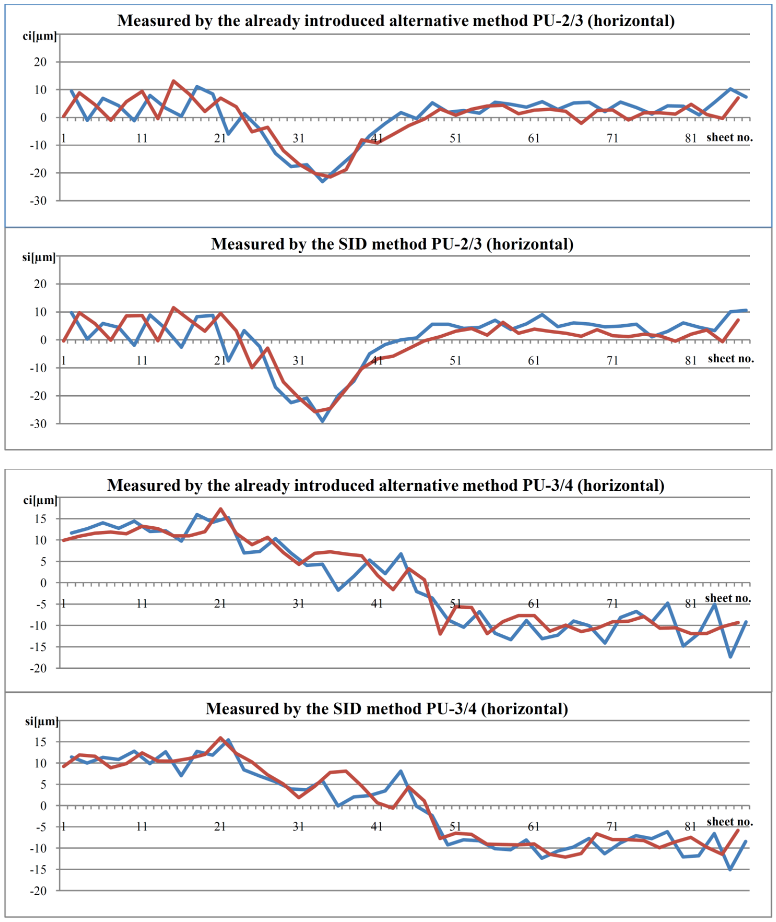

Figure 7. The comparison of register variation graphics between the SID-Luchs(si) and the introduced method (ci). The red curves demonstrate the odd and the blue ones the even results of register position.

88 consecutive printed sheets from this run were evaluated. Most of the modern sheet fed offset machines have double impression cylinders. Thus there are two different transport systems for the printing substrate in the press. Therefore every impression cylinder and every transfer cylinder has two different gripper systems. The register variation value of consecutive printed sheets will be evaluated separately for the first system in odd and for the second system in even printed sheets. That is necessary for analyzing the register variations for a modern press. That is the reason why the graphics (figure 7) are drawn with red (odd) and blue (even) curves.

Sheet no	statistic variabel	PU 2/3		PU 3/4	
		c_i [µm]	**s_i [µm]**	**c_i [µm]**	**s_i [µm]**
1 to 19	mean	-10	-12	3	3
	standard deviation	9	11	3	3
20 to 35	mean	3	4	-10	-9
	standard deviation	1	2	3	2
35 to 59	mean	3	4	-10	-9
	standard deviation	3	2	3	2
60 to 88	mean	1	0	2	2
	standard deviation	10	13	10	10
1 to 88	mean	-1	-1	-3	-3
	standard deviation	**9**	**11**	**9**	**8**

Table 1. The comparison of standard deviation between the SID-Luchs and the introduced method. Standard deviation is the most important data for the evaluation of register variation.

Comparison and Difference between the SID Value and the Alternative Method Value

The visual comparison of both methods (figure 7) shows a high affinity. The curves and the characteristics of both methods look almost identical. In table 1 the means and standard deviation of both methods are compared. The numerical results are very similar. The standard deviation value is the most important data for evaluating register variation. The maximum difference for standard deviation of both methods (table 1) was at most 2µm. It should be mentioned that the register variation varies depending on the location of the sheet. That means that only a few centimeters away from the measuring position can cause a difference of the value of the register variation compared to the first position. The comparison of different SID-Luchs elements in different position also delivers a difference to each other!

Conclusion

The suggested method for measuring the register variation can be an inexpensive alternative to the measuring method using image processing tools. The achieved accuracy is not as high as that of the image processing method, but the achived results of the proposed method are very good and satisfactory. One of the advantages of the proposed method is that this method is not so exclusive compared to the image processing method. The needed spectrometer are available in almost every printing company.

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