Establishment and Comparison of Different Definitions and Equations for a “Printability Coefficient” for the Flexographic Process.

Girard Leloup, Laurent*

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Abstract: The Flexographic Process has the last years noted a great improvement of the achievable quality. The quote part of the market for the flexographic printing process is still growing; working groups meet to achieve standards for this process at an international level. The industrial partners: paper manufacturers, peripheries suppliers, printers and converters are today looking for a common language to be able to judge, measure the print quality. The following paper will propose solutions for a universal language with the help of a “Printability Coefficient” for the Flexographic Process. The results of the research present different approaches for a mathematical modelling of the parameters influencing the printability and their interactions.

1. Objectives of the investigation

The work presented in this paper should be seen as a contribution to the actual effort for a standardisation of the flexographic process. The main objective of the investigation is to deliver the different actors in the packaging industry a key number to be able to objectively and with a guaranty of repeatability evaluate the quality of a printed product. This number called “Printability coefficient” is going in a first time to be used as an instrument in the quality control stage of the process and in a second time to be a tool for the conception phase of a new printed product. It will facilitate the dialogue between the different partners and also reduce the lost of time and money due to a luck of an universal quality language.

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*Research Corporation Media and Communication Technology (Framkom), Royal Institute of Technology (KTH), Stockholm, Sweden

2. Methodology of the investigations

The present work can be divided in different steps. Theses steps are the following: preparation of the printing trials, printing of the samples, measurement of the printability parameters, establishment and comparison of different equations for a printability coefficient. The first 3 steps are very time expensive in both the elaboration and realisation but are very important to achieve a valuable result in the final stage. The data collection (steps 1-3) results partially from the work achieved in preview research (1)(2) and (3).

2.1 *Preparation of the printing trials:*

The printing trials have been done on full-scale printing presses. These presses are located for the flexographic process at research centres in Germany (DFTA-TZ) and in Sweden (Framkom). The LEMO flexopress is a six-year-old six-colour CI-Press, with a width of 1300 mm and equipped with chambered doctor blades, CNC motors for the adjustment of the nip pressures and an automatic regulation of ink viscosity. The Aquaflex flexopress is a one-year-old, five-colour production stack press, with a 18" width. In the difference to the 2 others presses run with water based ink, the Aquaflex press was run with UV-ink. The third press, a Flexocompact eight-year-old, two-colour press with a 600 mm width is a modified production press used for research work. The capability and repeatability of the press have been tested in the past and show very good results (1).

In this study will be mentioned other printing processes like lithography, electrophotography and inkjet. These processes are not the main focus of the present report but have been used as references for the establishment of the different printability coefficients. Some of the printing trials evaluated for the work are described in details in a project called "Provtryckning 2000" (4).
The preparation of the trials consists to a selection of different substrates, a definition of the printing parameters, an elaboration of the printing procedure and the coordination of the different research resources involved. The substrates range covers with 11 qualities (figure 1) from matt and gloss paper, uncoated liquid packaging board, liner to high coated boards a broad palette of the flexographic products.

N.	Designation	Specification
1.	SEUE	LPB-Edge reel not calendered
2.	SEUE1	LPB-Edge reel - calendered at 75 kN/m
3.	SEUE2	LPB-Edge reel - calendered at 130 kN/m
4.	SEUM	LPB-Middle reel - not calendered
5.	SEUM1	LPB-Middle reel calendered at 75 kN/m
6.	WT1E	WT-Edge reel not calendered
7.	WT1M	WT-Middle reel not calandered
8.	IG	Highly coated matt paperboard
9.	IA	Highly coated gloss paperboard
10.	SB Gloss	Highly coated gloss paper
11.	SB Matt	Highly coated matt paper

(LPB: Liquid Packaging Board - WT: White Top 140g/m2 – I: High quality board 220-250g/m2 – SB: Graphic Art paper 130g/m2)

Figure 1: Table with the different substrates

The printing parameters have been adapted to the substrate. For the qualities 1-7, the printing plates are 1.70 mm DPS and HOS plates with anilox rollers offering volumes of 8 and 12 cm3/m2. For the qualities 8-11, the printing plate is a 1.14mm DPN plate with an anilox roller volume measured by 3-5 cm3/m2. The different substrates allowed at the same time to test different plates both conventional and digital and anilox rollers from high volumes to very fine gravure and less volume.

2.2 *Printing of the samples:*

Not only the substrate and printing parameters are variables in the investigation. 2 different printing procedures have been chosen to validate the printability coefficient. The first procedure (substrate 8-11) is an optimisation of the result. This optimisation has for goal to allow a correlation between the technical measurements and the visual perception. The printing trials have been effectuated in 3 steps: the printing of a test form for the realisation of a colour management profile, the gravure of new plates with the profiles (UV and water based ink generated 2 different profiles) and the final printing by running the same densities.

The second procedure (qualities 1-7) is the direct printing of a known test form by varying the ink transfer parameters. For different ink quantity, a range of nip pressure has been printed with a cyan water based ink. The results are "good", "less good" and "bad" samples, which allow a scaling of the printability coefficient.

2.3 *Measurement of the printability parameters:*

To be able to establish a printability coefficient a large volume of measurements are necessary. The measurements methods are already described in precedent papers (3) and (4). The results of the measurements are going to be presented with diagrams and tables will show the principle values. All the values are available but not presented here!

The measured parameters are:

- For the qualities 1-7: densities in 2%, 50% ton value and in the solid area, edge sharpness divided in wicking and bleeding components, dot gain by a densitometric (for the 50 %) and optical way (for the 2, 30 and 50%), mottling in 30% screen and in the solid area, dot quality (roundness) for 2 and 30% dots.

- For the qualities 8-11: densities CMYK in the solid area, edge sharpness divided in blurriness and raggedness components, dot gain by a densitometric way in 40 and 80% for CMYK, mottling for C and K as for Red (R=100%M+100%Y), Green (G=100%C+100%Y) and 40% K, gloss, colour gamut, colour failure and grey balance.

Not all the parameters will be retained in the "final" printability coefficients but all of them have been available and tested to find the best compromise.

2.4 *Establishment and comparison of different equations:*

The first stage of the work is to test different equations for a printability coefficient and to look at the correlation with the visual perception data for all the printing processes. In a second step the equation will be optimise for the flexographic process. This optimisation has for goals to get a better correlation with the visual perception data and to simplify the equation. The simplification will put in relief the components of first priority, the printability parameters specific for the flexographic printing process. The obtained result will then confronted to the qualities 1-7 by varying the printing parameters and comparing the values with the expected results.

3. Results

3.1 *The results of the measurements:*

In this part will be presented the results of the different measurements. The goal of this study is not to find the combination substrate / printing parameters to obtain the best quality but to establish a relevant printability coefficient. Therefore it does not appear necessary to present the results of the measurement as raw data but more interesting to show the variation in the results for the different measurements. The amplitude of the variation should be seen as a quality factor for the printability coefficient.
All the following diagrams (figures 2 to 6) has been build on the same principle: the minimum, the maximum and the mean value of each measured parameters have been picked up, then the difference between the max and min to the mean value have been calculated in % of the mean value and plotted by property for the different substrate quality groups.

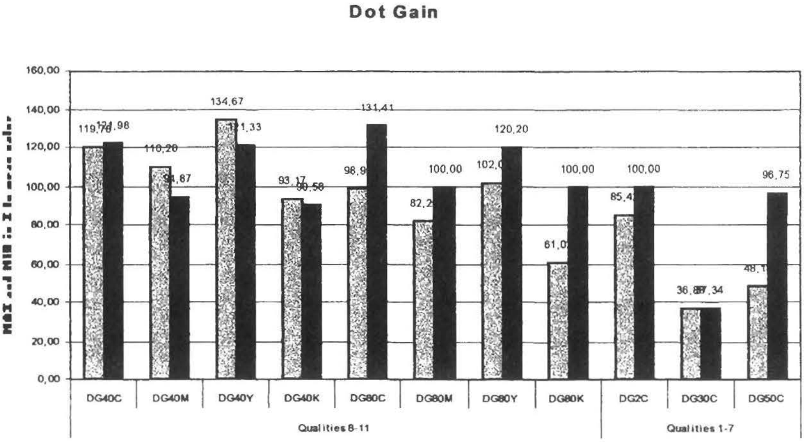

Figure 2: Amplitude of the Dot Gain variation for the different substrates

The dot gain diagram shows a regular repartition of the amplitude on both side of the mean value for all the measurement except for DG80K and DG50C. The summed amplitude is about 200%.

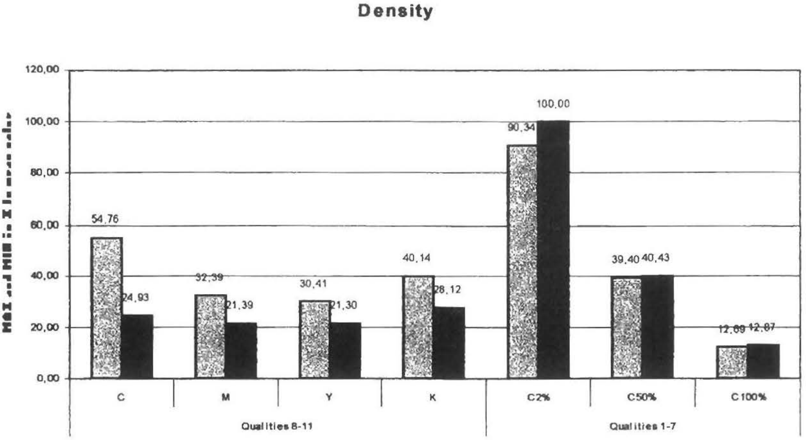

Figure 3: Amplitude of the Density variation for the different substrates

The results for the density are as expected: about the same variations in CMYK, for the minimums and larger variation for the maximums due to the inkjet process and its very high densities. C 2% with values around 100% can be explained with the small nominal value.

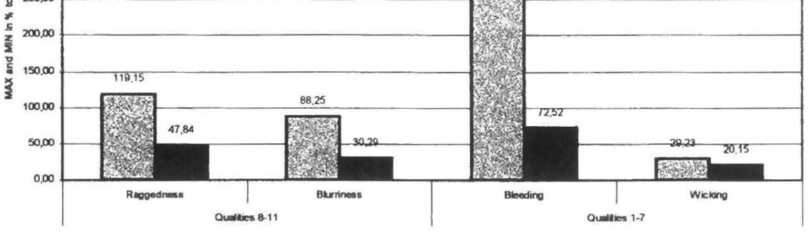

Figure 4: Amplitude of the Edge Sharpness variation

The edge sharpness is a typical quality characteristic for the inkjet and flexographic processes. Raggedness, blurriness and wicking are quantifications of the quality for positive lines and bleeding for negative lines. One more time the extreme values are the maximum values. The over 400% in bleeding correspond to a for low nip pressure. The minimum values are between 20.15 and 72.52%.

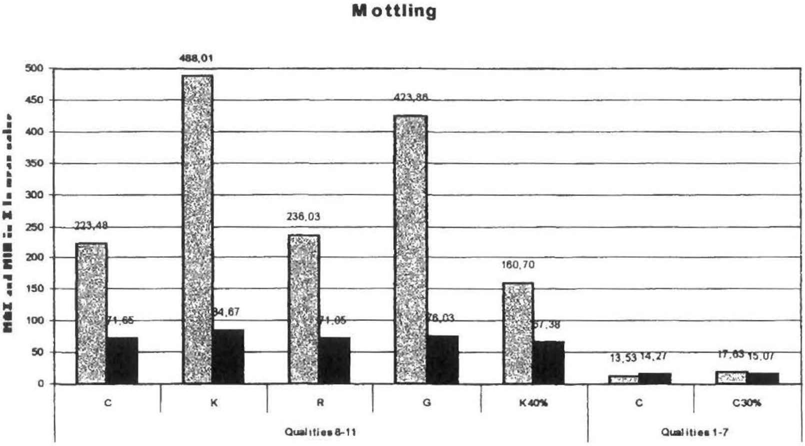

Figure 5: Amplitude of the Mottling variation for the different substrates

The mottling diagram can be interpreted at 3 levels. The first conclusion is only a confirmation of the large influence of the printing process on the mottling values: the max values are very far away from the mean values. A second observation is that the minimisation of the mottling is not quantitatively dependent from the colour, trapping or screening of the measured surface. Moreover the mottling is a factor is for a specific process (flexography in this case) very stable in the amplitude of the variation: 13.53 - 17.63% for min/max C and C30%.

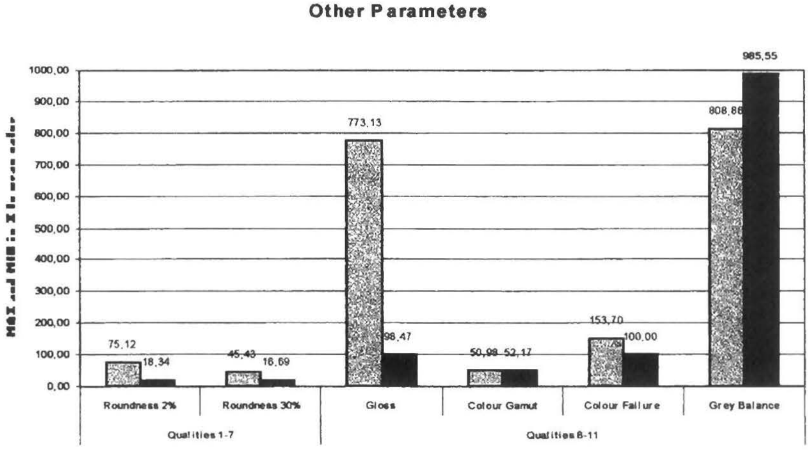

Figure 6: Amplitude of "other parameters" variation

To measure the roundness is a method to look at the dot quality (the ideal circular point has a 1.00 roundness). This measurement gives together with the dot gain a very good characterisation of the dots. The other parameters presented in this diagram are more relevant to compare the different printing processes than to judge each one separate. Grey balance notices very surprising results: the use of ICC profile has been done for the trials!

3.2 *The establishment of the printability coefficient:*

3.2.1 Definition of the printability

The printability of a substrate has different definitions depending who is speaking and in which context. The paper industry has of course not the same definition as the IT industry but not either the same as the printing industry. However are these 3 industries (at least 2 of them) working in very eng connection. The admitted definition of printability for this work is the following: Measurement of the printed result quality related to the substrate properties and the printing parameters.

3.2.2 Different equations

a. correlation to the virtual perception data:

The establishment of a printability coefficient for the flexographic process has been done in successive steps. The first step was to find the best linear combination of the measured printing quality parameters which fits with the visual perception (VP) quality evaluated for the flexographic samples. The goal was to obtain an equation valid for the flexographic process by minimising the distance between both printability (measured/calculated and visual) but at the same time keeping the shape of the printability curves parallel for the other processes. The results of the different printability values (P) are presented in the figures 7 to 17.

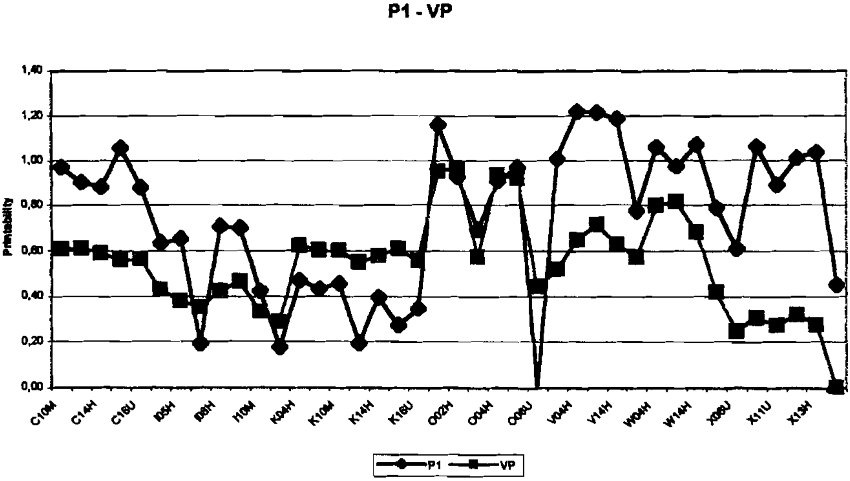

Figure 7: Plot P1 – Visual Perception

P1 is a linear combination of all the quality parameters measured for the substrates 8-11. For the parameters with several measurements, like densities, mottling, ... the arithmetic mean has been calculated and used as input for the equation.

$$\mathbf{P1}=1-\left[\left(1/\left(\max \sum \alpha_i A_i\right)\right) * \sum \alpha_i A_i\right] \qquad (5)$$

with $\alpha_i = +/- 1$
+1 for mottling, blurriness, raggedness, dot gain, colour failure, grey balance
-1 for density, colour gamut, gloss
A_i printability parameters

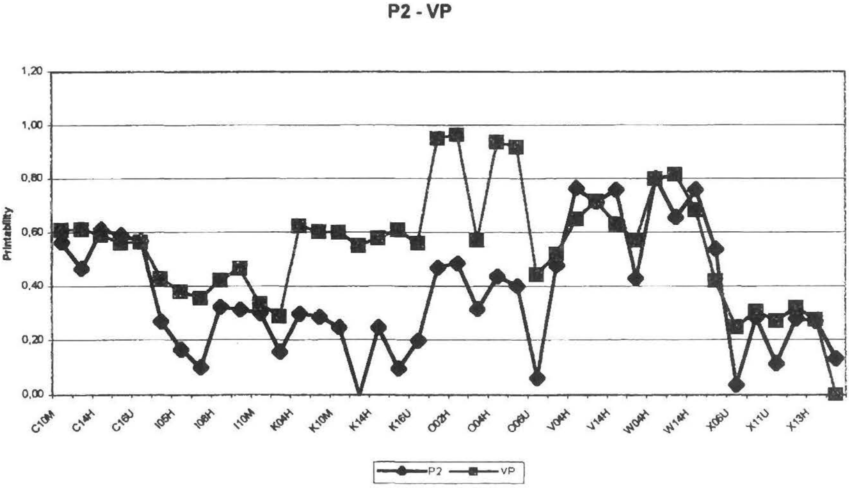

Figure 8: Plot P2 – Visual Perception

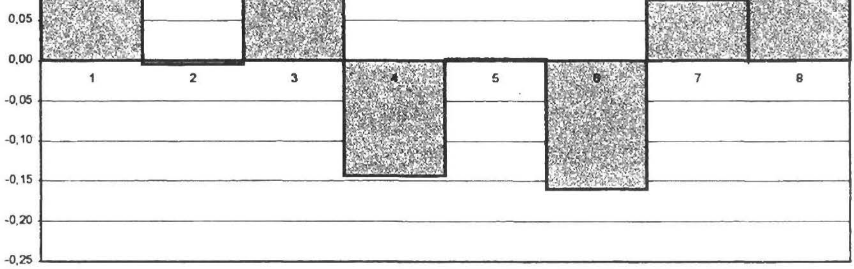

Figure 9: Distance P2 to the Virtual Perception printability

P2 is a simplification of P1. The parameters qualified as "other parameters": gloss, colour gamut, colour failure and grey balance has been eliminated from the equation. The α_i coefficients are still +/- 1. The figure xx shows the distance of P2 to the visual perception printability. All the values are in a range between -0.16 and + 0.15. These values show that the equation can be used as basis for a credible printability coefficient.

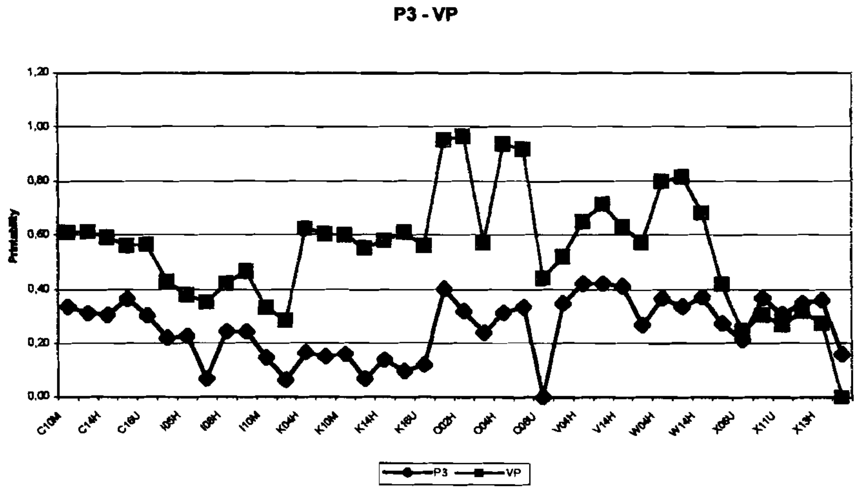

Figure 10: Plot P3 – Visual Perception

P3 is a trial to take in consideration by an other way the fact which high values for density, colour gamut and gloss are suitable for a good quality.

$$P3=1-\left[\left(1/S * \left(\Sigma(1-A_i)+\Sigma A_j\right)\right]\right. \quad (6)$$

with $S=\max\left(\Sigma(1-A_i)+\Sigma A_j\right)$

A_j : mottling, blurriness, raggedness, dot gain, colour failure, grey balance

A_i : density, colour gamut, gloss

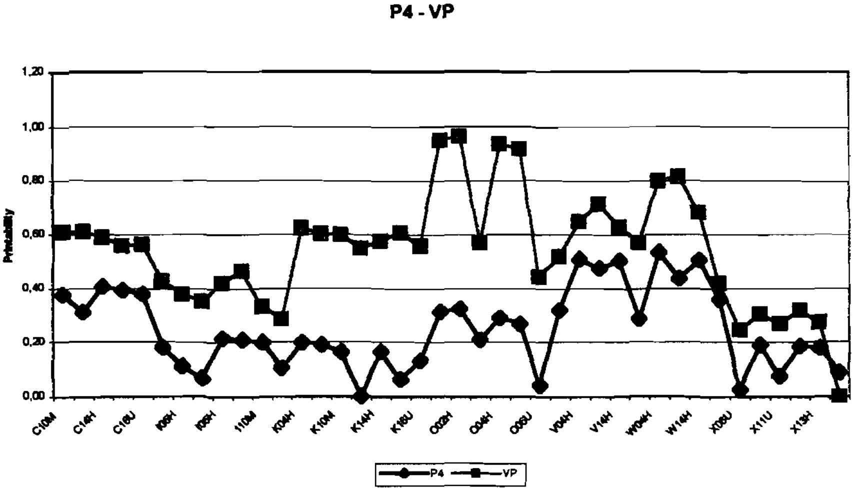

Figure 11: Plot P4 – Visual Perception

P4 is built on the P3 model by the same principle as P2 on P1.

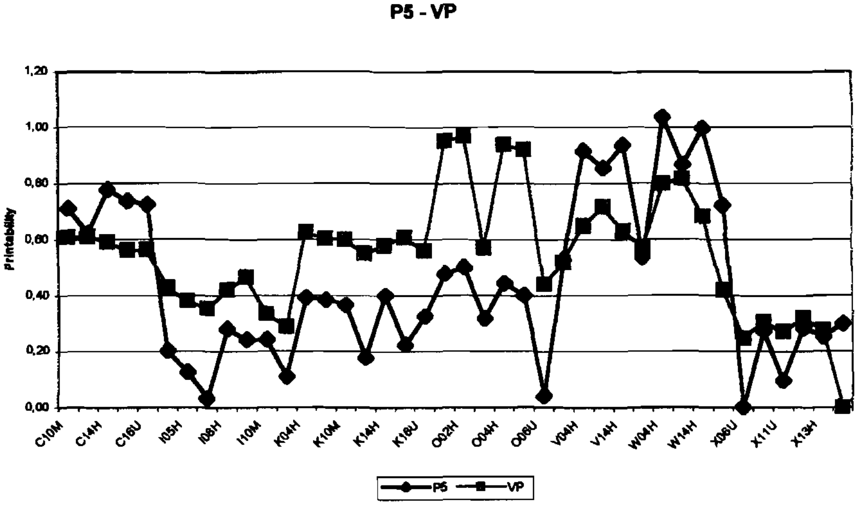

Figure 12: Plot P5 – Visual Perception

$$P5 = 1 - \left[\left(1 / \left(\max \sum \alpha_i A_i \right) \right) * \sum \alpha_i A_i \right] \qquad (7)$$

with

$\alpha_i = +1$ for mottling, dot gain

$\alpha_i = -1$ for density
$\alpha_i = 1/2$ for blurriness, raggedness

A_i printability parameters

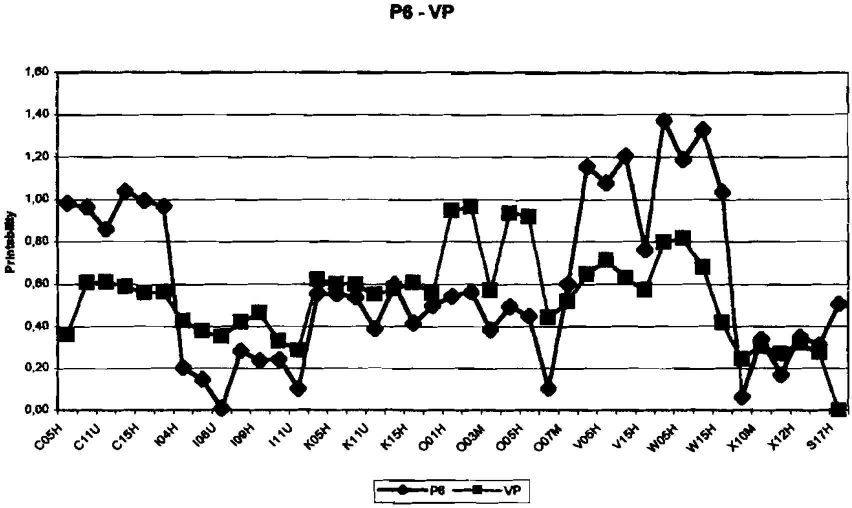

Figure 13: Plot P6 – Visual Perception

$$P6 = 1 - \left[(1/(\max \Sigma\alpha_i A_i)) * \Sigma\alpha_i A_i\right] \qquad (8)$$

with
$\alpha_i = +3$ for mottling
$\alpha_i = +4$ for dot gain
$\alpha_i = -4$ for density
$\alpha_i = +1$ for blurriness, raggedness

A_i printability parameters

P5 and P6 are both using the same raw data as P4 but the difference is the weighting of the different quality parameters. P5 is a trial to regroup raggedness and blurriness under a sharpness factor by weighting both parameters with 0.5. P6 is more ambitious and is recalculation of the printability coefficient by distribution of 13 weighting. The weighting corresponds to the number of measured fields for each parameter (CMYK=4, mottling 40%, one colour, overprint = 3).

b. Definition of a flexographic specific printability coefficient:

The second step was to confront the best model to the flexographic process. This has been done by varying printing parameters like plate, volume of the anilox roller, nip pressure for different substrates.

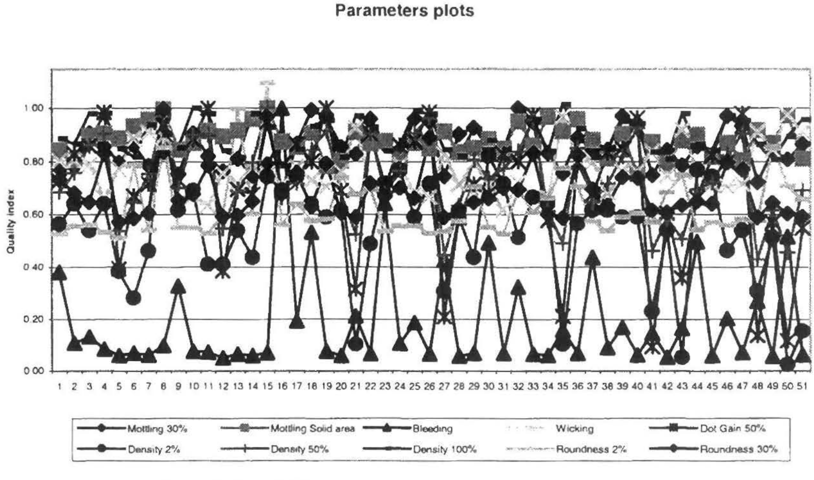

Figure 14: Plot of the different quality parameters for the flexography

The figure 14 is only here to show the necessity of a printability coefficient. The interpretation of such a diagram is impossible and a method is needed to visualise the results.

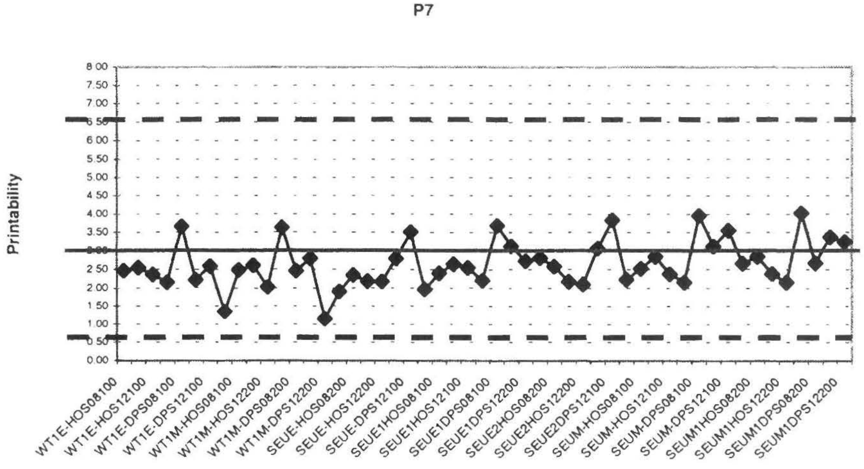

Figure 15: P7 for different plate/anilox/nip pressure/substrate combinations

P7 is an adaptation of the P2 model for the quality 1-7. The equation has a similar construction. Moreover the quality parameters are this time specific for the flexography:

- uniform coverage: density, mottling solid area, mottling 30%
- line quality/edge sharpness: bleeding, wicking
- dot quality: dot gain, roundness

$$\mathbf{P7} = \sum \alpha_i \,(1-A_i) \quad (9)$$

with α_i = +/- 1

+1 for mottling 30% and solid area, wicking, bleeding, dot gain 2%, 30% and 50%, roundness 2% and 30%

-1 for density 2%, 50% and full tone

A_i printability parameters

MAX: 4.02 – MIN 1.14

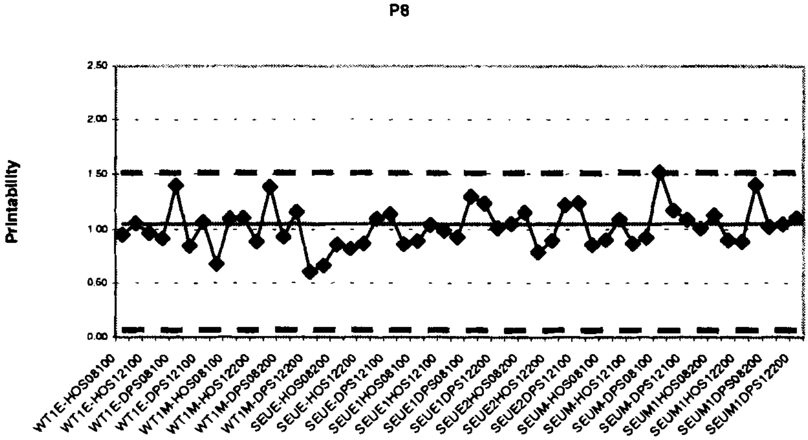

Figure 16: P8 for different plate/anilox/nip pressure/substrate combinations

P8 is a moderation of the printability coefficient P7 by weighting of the quality parameters. The principle of the weighting is to regroup factors of same contribution for a quality quantification and to give them together the same weighting (=1).

$$\mathbf{P8} = \sum \alpha_i \,(1 - A_i) \quad (10)$$

with α_i = +/- 1
+1/2 for mottling 30% and solid area, wicking, bleeding, roundness 2% and 30%
+1 for dot gain roundness 2% and 30%
-1/3 for density 2%, 50% and full tone

A_i printability parameters

MAX: 1.52 – MIN: 0.60

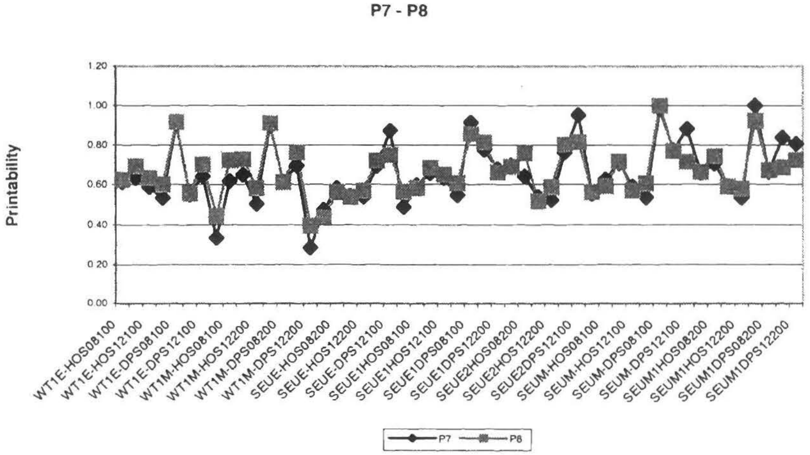

Figure 17: Comparison P7-P8 printability for different plate/anilox/nip pressure/substrates combinations

4. Discussion

The investigation has delivered 8 equations for a printability coefficient. The way the work has been conduced gives a logical orientation to the discussion for the establishment of a printability coefficient for the flexographic process. But before to study in details the final propositions P7 and P8, it is interesting to have a look at the P1-P6 coefficients. P1-P6 has been obtained by trying different linear combination of selected print quality parameters. The amplitude of the variation (see results part I) and the large number of substrates tested allow to make a credible analysis.

P1 is for example very well adapted to the offset process (O). The shape of the curves are parallel and the distance between the plots are very limited. P2 has been used to construct the flexographic printability coefficient. P3 shows a very accurate compatibility with the Inkjet process (X). P4 and P5 can be qualified as neutral equations which can be used for example comparing to printing process: the curves do not correlate as well as for the other equations but the point for point deviation is almost constant. P6 finally seems to be the right alternative for the digital printing technology (I and K).

The flexographic specific part of the diagrams (U and V) is described by the equation P2. The form of the equation has also been kept for the second phase of the work and the establishment of the coefficient P7 and P8. The modification brought to P2 to obtain P7 and P8 had for objective to more precisely take care of the different flexographic specific parameters, both printing and quality parameters. The results confirm both the expected results and the visual judgement.

The choice to use P7 or P8 depends of the panel of substrates to be tested: P8 could be employed for a first approach and P7 for a finer study.

5. Conclusion

The present study has delivered valuable results. The most interesting result for the flexographic industry is that the possibility to have an objective quantification of the printability has been proved. This quantification called "Printability Coefficient" offers the printing and paper industries a simple comparison instrument. The numbers obtained can in the future be scaled and conduced to new development of the P7-P8 equations but it has been shown that the choose of the parameters and the form of the equation should be kept.
The next step of the work should be to use these equations for a prevision of the printability and not only as a quality control instrument.

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