MODELING THE INKING SYSTEM OF AN OFFSET PRESS BY MEANS OF A LASER DEVICE

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Abstract: In this paper is presented an experimental approach for the design of digital models towards the automatic control of the inking level in an offset press. The obtained models depend on the influence of the paper grade, the dot area and the press speed in the process. These models offer a possibility to describe the basic mechanisms produced by a change of the ink flow in the printing press.

The main feature of this study is the use of a laser device which is developed in the laboratory of EFPG in order to carry out an open loop identification of the inking system.

The experimental results are directly treated by computer; they illustrate the validity of the proposed models.

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1. Introduction

The quality of an image produced by the offset process is highly correlated to the process itself and to the way it is used. Theoretically, it is possible to link the image quality to the various parameters describing a press run. To establish the corresponding relationships, it is necessary to consider the image as a physical body and to substitute to the human eye a measuring device which may be sensitive to some variations in the process; this device is a laser sensor, as initially presented by Balducci (1990) in the case of the control of the fountain solution flow.

The target of our work is to study if it is possible to use a similar device to control the ink flow in the running press and to rectify deviations of a printed image in a minimum delay by means of automatic command. To design the corresponding system, it is helpful to describe the behavior of the printing press through a model which may subsequently be used to develop a command algorithm and/or to calculate its best setting. A graphical technique connected to the input/output variables of the system will be successfully used for the determination of a "process behavior" model.

2. Some words about models

The development of a model adapted to any physical system may be performed with the aim of a better understanding of on-going phenomena. In our case, a model is determined for the design of a command system (logical sensors and/or state estimators of the process). Furthermore, it is important to precise that the kind of models we need belongs to the dynamic category. Such models are usually classified in two sets :

a- "knowledge" models : they are based on the physical laws which govern the system. Their main objective is to explain any phenomenon by means of a mathematical relation. They are likely to be complex as they generally include many parameters;

b- "behavior" models : they are very often intended to be valid in a restricted variation area in the neighborhood of a "setting point".

The way we modelize an offset press has to be as general as possible and should be applicable to various printing machines. Nevertheless, our experiments were performed on the two colors sheetfed press of EFPG (Roland Favorit). The laser sensor has been developed and improved in our laboratory (Curtil, 1996). The configuration of the whole measuring set is schematically presented in the figure 1.

3. System analysis

This paper deals with the inking system of a press and with the parameters which may affect its dynamic behavior; these variables are classified as follows :

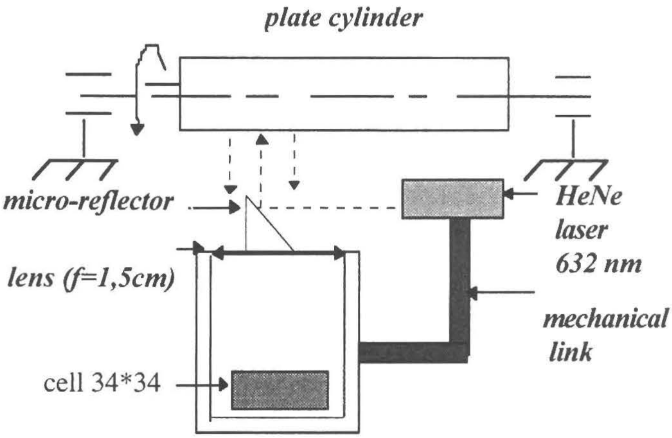


Figure -1- Configuration of the whole measuring set

a- input variables : they may be intentionally varied and they influence the evolution of the machine; in the case of the inking system of an offset press, there are two main input variables :

- the speed of the inking roller which is named **Vi**; this speed is proportional to the speed of production **Vp** of the printing machine; thus :

$$Vi = k.Vp$$

where **k** is an dimensional constant; we may express **Vp** in copies (or sheets) per time unit. To vary **Vi**, we may vary **Vp**, but this action has no effect on the ink amount on any printed sheet ; thus, the only possibility to promote this effect is to vary the value of **k**; usually this constant is expressed as a percentage of its maximum value (which, in turn, is set by the machine supplier);

- the gap between the surface of the inking roller and a given inking drawer we called **d**; this gap may be modified by the pressman during the run; it is usually expressed in arbitrary units from 0 to 16 .

There exists another input variable which is the frequency of the vibrator, but we did not take it into account because it is set constant during any press run; it is also to notice that this parameter is not meaningful for rotary presses.

b- output variables : they are usually measured parameters; in our work, it should be a quantity to be correlated to the image quality : classically, the optical density **D** of the print is suitable for this purpose; but, as will be shown, under given conditions, the density behavior may be fairly correlated with the laser sensor signal **Yc** behavior which appears in the form of variations of an electric potential.

The process may also be characterized by other parameters which can (or cannot) be measured; two of the measured ones may be the paper grade (through surface topography) and the relative dot area on the printing plate; any change affecting these parameters are to consider as measured perturbations

Pm; among the uncontrolled (thus unmeasured) quantities **Pr**; we may find the temperature of the rollers, the pressure in the various nips and the electronic noise affecting the sensor signal. The figure 2 describes the inking system with its two input variables, its output signal **Yc**, and possible perturbations.

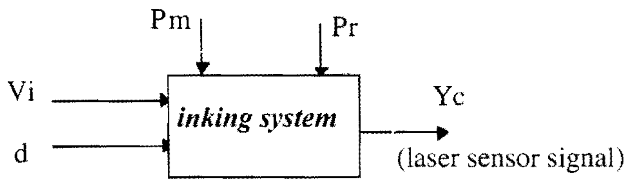


Figure -2- The inking system model

4. The "black box" behavior model

This kind of model is intended to study the behavior of the input/output of the process without taking care of what is involved inside it. As shown by Has (1995), a theoretical model of the ink flow in the inking system may be developed without referring to a given printing press. The author extends a proposition by Schmitt (1978). Let us recall some information about this work : for a given zone (positioned at abscissa **x** along the cross direction) in the inking system, **E** being an input function (depending on the input variables plus time t) and **A** an output function, Has (1995) writes the following equation :

$$(1) \qquad E(x,t) - A(x,t) = \frac{\partial Q(x,t)}{\partial x} + \frac{\partial S(x,t)}{\partial t}$$

The input function **E** is connected to the ink feed; it thus depends on both **d** and **Vi**. For our purpose, the output function **A** will be linked to the laser signal as follows :

$$(2) \qquad A(x,t) = a\,Yc(x,t)$$

where **a** is an "ad-hoc" constant. Two other quantities are found in the relation (1) : **Q** represents the ink amount which circulates transversely (parallel to the cross direction), and **S** is the ink amount which is not transferred to the plate (or the paper) in the studied zone.

Without re-entering the whole calculation, we notice that Has (1995) is led to a differential equation describing the behavior of the optical density **D** reacting to a step perturbation of the input which has been retrieved in the step perturbation on one of the input variables. We propose work of Mac Phee (1996). In an analogue fashion, supposing that the effect of each input variable (**d** or **Vi**) may be separated from the other, we are similarly led to two differential equations as follows :

$$(3) \qquad \frac{Yc(t)}{dt} + \frac{1}{T_1} Yc(t) = C_1.f_1(d, t - \tau)$$

$$(4) \qquad \frac{Yc(t)}{dt} + \frac{1}{T_2} Yc(t) = C_2.f_2(Vi, t - \tau)$$

where τ is a delay and, if j=1 or 2, $\mathbf{f}_j$ is a function describing the dependence of the input function **E** on the input variables (**d** for j = 1, and **Vi** for j = 2). In the equations (3) and (4), $\mathbf{T}_j$ are time constants and $\mathbf{C}_j$ are ad hoc constants connected to the ink capacity of the whole inking system (see Has 1995).

For further use, we wish to determine the values of the delay **t** and time constant $\mathbf{T}_j$, the later corresponding to the time after which inking (and, thus **Yc**) may be considered stabilized. In order to determine those constants, a graphic technique (Broïda's method) is used. Let us call **F**(p) the Laplace transform of **f**(t) (see Appendix). The transformation of equations (3) and (4) is straightforward :

$$(5) \qquad H_1(p) = \frac{k_1.e^{-\tau p}}{1+T_1 p}$$

$$(6) \qquad H_2(p) = \frac{k_2.e^{-\tau p}}{1+T_2 p}$$

where, **Yc**(p) being the Laplace transform of **Yc**(t), $\mathbf{H}_j(p)$ is the so-called "input/output ratio" or "transfer function" given by :

$$Hj(p) = Yc(p) / Fj(p)$$

and $\mathbf{k}_j$ are new constants given by : $k_j = C_j.T_j$

The following approach will allow us to identify the model parameters τ and **T**. The Broïda's method is well fitted for the identification of first order models including a time delay. It consists in drawing the "response curve" to a step variation of an input and to determine the time t_1 and t_2 (see figure 3) when the response reaches respectively 28% and 40% of its final value. The time constant T and the delay t are given by :

$$\tau = 5.5\,(t_2 - t_1) \qquad \text{and} \qquad T = 2.8\,t_1 - 1.8\,t_2$$

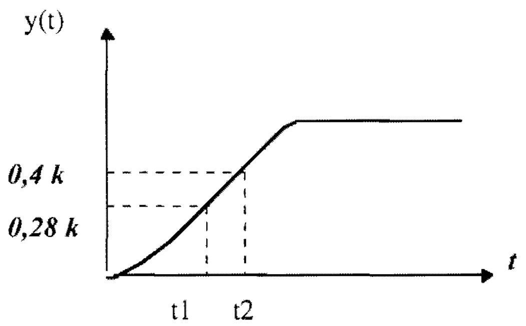


Figure -3- Broïda's method

5. Experiments

Before identifying the various parameters of our model, let us determine the sensitivity of the laser sensor to ink variations. On the one hand, this problem is very important because it has been previously well established (Curtil 1996) that the sensor signal varies with the fountain solution amount on the offset plate : the target is, in our view, to look for a domain where its sensitivity to "water" should be reduced enough to become negligible in front of that to ink variations. On the second hand, it is also important to compare the signal behavior with a quality correlated parameter like the optical density. The figure 4 presents a schema of the printing form; it mainly consists in little areas with a 80% coverage (on the film) surrounded by large zones with a 30% dot area. The experiments were carried out with a primary cyan ink.

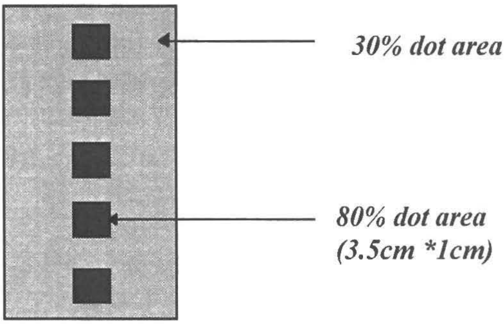


Figure -4- Printing form (A3)

In the first trial, setting the speed constant, we applied a positive step (increasing the ink feed) with a duration of 300 sheets and an amplitude of 3 arbitrary units (from 7 to 10 units) of the drawer aperture. The measurements of both the sensor signal from the plate and the optical density on the printed paper were equally made on the 80% zones (figure 5a and 5b) and 30% zones (figure 5c and 5d). The figures 5a and

5b show that the sensor sensitivity depends on the dot area percentage : there is a significant variation of the signal value for the 80% dot area and not for the 30% zone (given the noise level of the signal). On the contrary, it has been shown (Curtil 1996) that the sensor sensitivity to fountain solution varies on the opposite way. This feature is important because it allows us to use the measurements on the 80% dot area zones to carry out the identification of the model parameters.

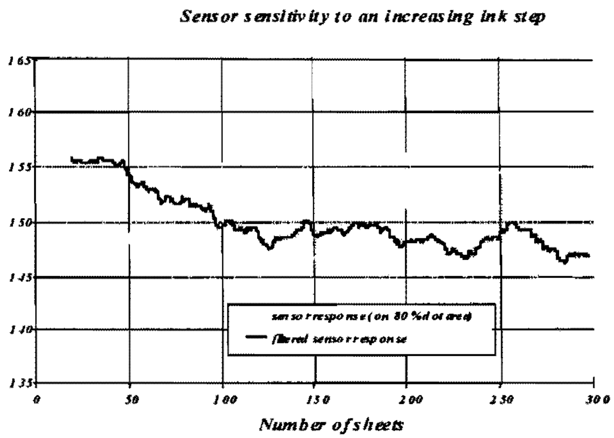
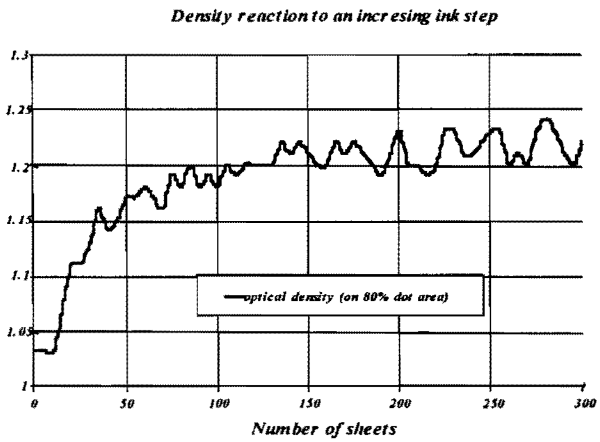


Figure -5a-



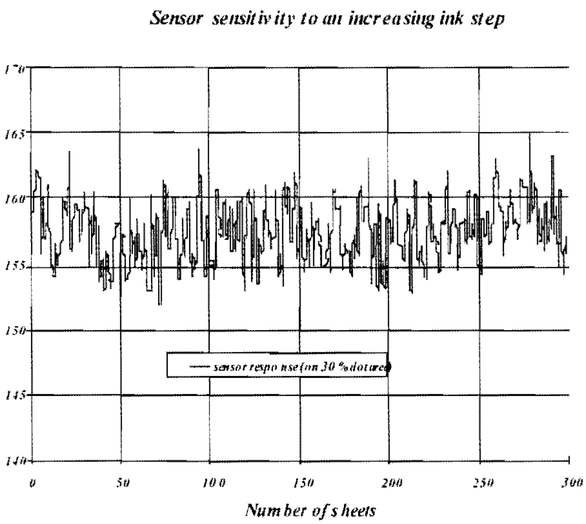


Figure -5c-

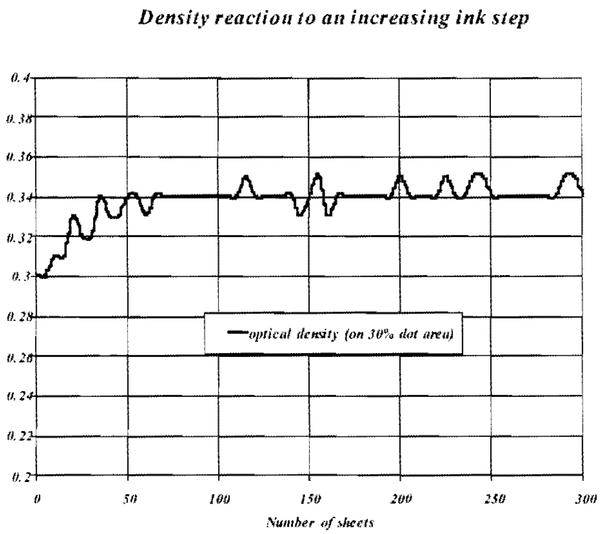


Figure -5d-

In the second trial, we applied a negative step (decreasing the ink feed) with a duration of 400 sheets and an amplitude of 10% (from 90% to 80% of the maximum value of the constant **k**). The results correspond to a 80% dot area zone; they are presented in the figure 6a for the sensor signal and 6b for the optical density values. The two graphs show significant variations of both parameters ; this feature allows the drawing that they may be correlated to one another.

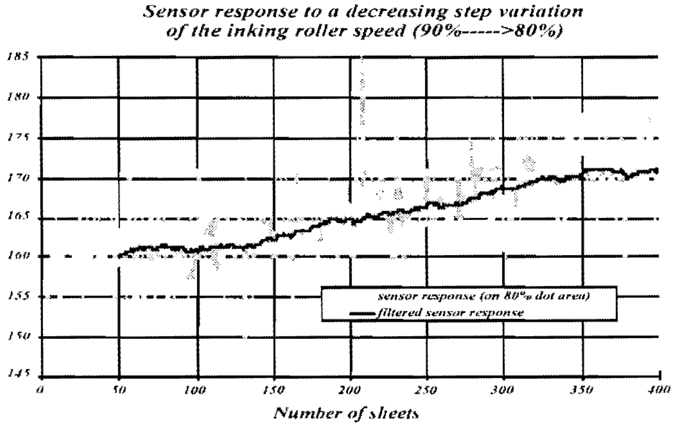


Figure -6a-

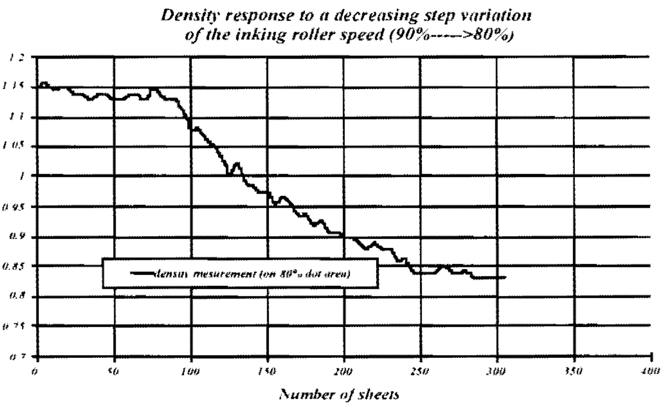


Figure -6b-

6. Using Broïda's method

As presented in the third section of this paper, the inking system of an offset press exhibits two input variables and one output parameter, which is chosen as the sensor signal. Thus, its "process behavior" model may be described as presented in the figure 7. Using the Broïda's method for a smoothen signal value (as in figure 5a, for instance), it is possible to obtain the following results from the 80% dot area zones :

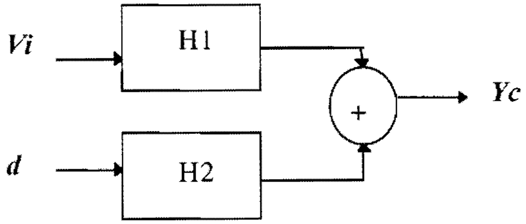


Figure-7-Transfer functions of the inking system

Step kind	Positive (1st trial)		Negative (2nd trial)	
	τ	T_1	τ	T_2
Sensor signal	38	72	38	139
Optical density	44	78	44	145

The time constants T_1 and T_2 are significantly different, this result is in agreement with the findings of Has (1995). Dealing with the delays, the difference between the sensor signal and the density measurement may easily be explained by the distance separating the plate and the offset press delivery which approximately corresponds to six sheets.
The figures 8a and 8b present the validation of the two models in the form of the coincidence between calculated values (from the graphic method of Broïda) and filtered and centered experimental sensor signal values.

Model validation of the input 1 (d)

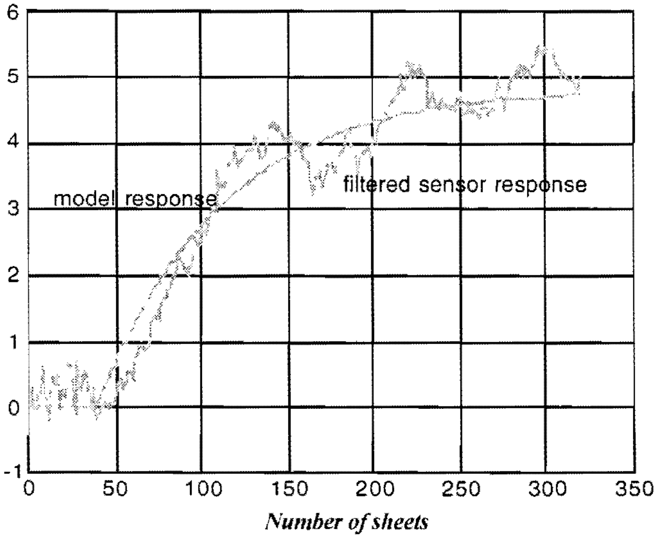


Figure -8a-

Model validation of the input 2 (Vi)

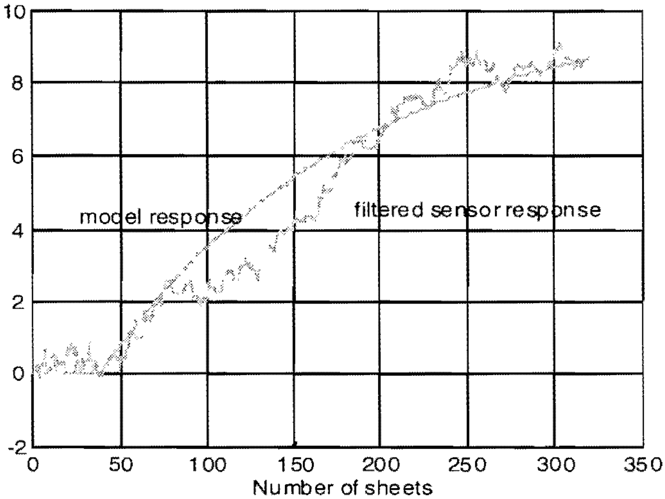


Figure -8b-

7. Conclusion

The results presented in this paper are part of a large research work involving several persons; they may be summarized as follows :

1) It is possible to describe the inking system of an offset press through the two input variables **Vi** and **d**, one output variable **Yc** and various perturbation parameters.

2) The laser sensor is able to detect inking level variations in the range of high dot area coverage. This property allows the minimization of deviations caused by the fountain solution within the noise level of the device. The sensor remains to be studied in order to enhance its sensitivity to the desired input parameters and consequently to improve its Signal/Noise Ratio.

The position of the sensor just in front of the plate allows the identification of the real delay of the alone inking system, and thus allows to rectify more rapidly the input values.

3) A simple "process behavior" model based on a graphical method is presented and seems to work well. Such a model is likely to help us to calculate a regulator for the offset process which should maintain the inking level to its best value and reach it as fast as possible. Furthermore, it will become possible to include the regulator in a closed loop system through the use of digital techniques like the least squares- or the "model" method (Flaus 1994).

8. Acknowledgments

The published studies by M. Has was very helpful in developing the graphic model presented here. The authors are also very grateful to Martine Rueff for her interesting discussion and for her great help in the models validation.

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10. Appendix : The Laplace Transform

The Laplace Transform of a given function f(t) is defined by :

$$L[f(t)] = F(p) = \int_0^\infty e^{-pt} f(t)\, dt$$

Its basic properties are its linearity and the replacement of a derivation (or integration) by a simple multiplication (or division) :

$$L\left[\frac{df(t)}{dt}\right] = p\,F(p) - f(0^+)$$

$$L\left[\int_0^\infty f(t)\,dt\right] = \frac{F(p)}{p}$$

$$L[f(t-\tau)] = e^{-\tau p}F(p)$$