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DEVELOPMENT AND RESEARCH OF INFORMATION MODEL OF INK COMBINATION PROCESS IN MULTI-INK ROTARY WEB PRESSES

Oleksiy Shevchuk
Ukrainian Academy of Printing,
Str. Pidgolosko, 19, Lviv, Ukraine. E-mail: uad_wiz@ukr.net

Алексей Шевчук
Украинская академия печати
Ул. Пидголоско, 19, Львов, Украина. E-mail: uad_wiz@ukr.net

Summary. The article reviews the task of design of information model of the ink combination process oin multi-ink rotary web presses, which is caused by the change of elongation and growth of the tape speed in the area. The analysis and research of the system of automatic control of ink combination has been done. The research of parameters of the systems of tape tension PPM in the environment MATLAB has been carried out. Methods of technological process combination performed on the tape, and synthesis of relevant models have been reviewed. The information models of automatic control of ink combination have been developed. The results of computer simulation have been presented.

Key words: rotary web press, information model, movable tape material, combination of operations, computer simulation.

SET OF PROBLEM

During the movement of the tape material through the section of a rotary web printing press other technological operations are performed as well (folding (bending), die-cutting, punching, trimming, etc.). In the process of these technological operations there take place some actions to the tape, causing its deformation. In the area of contact with the leading and printing cylinders there is slippage and deformation of the tape. During technological operations the tape is under the variable influence of moisture and temperature (ink applying, moistening, drying), causing significant deformation (elongation or shrinkage) of thin tape materials such as paper, cellophane, etc. [1].

Tape-driven cylinders and working units of presses (plates and printing cylinders, rotary blades, drills) may have uncoordinated movement because of deviation of cylinder diameter from the nominal size and because of the backlash, elastic vibrations, weariness of kinematic pairs, etc. [2, 3]. This non-coordination can cause increasing the technological operations shift in the case of independent mechanisms individual drive. A significant non-coordination of movement of the tape and working units occurs at transient operating conditions (start, stop, speed change) [3]. As a result, we violate the correspondence between cyclical working units and cycles of supplying the printed tape to these units. For the combination of technological operations performed on the tape, we need not only full equality of speeds (synchronicity of movements) of the tape and working units, but syn-phases of their movement. In this regard, we have the problem of management combining various technological operations performed at tape processing. This problem is called the support of the register [3, 4]. Under the register we understand a certain position relatively to working cylinders in each particular time.

To control rotary web presses we use the systems of automated electric drive, systems of automated adjustment of tape tension when it is unwound and wound into the roll, system of automated ink combination and others.[3, 5-10]. The increased requirements to the quality of the printed matter demand the design of new highly efficient systems of automatic ink combination and optimal adjustment of the existing ones.

ANALYSIS OF RECENT RESEARCH AND PUBLICATION

The article [11] presents the method of calculation of technological operation sequence for the criterion of minimizing of its duration. The sequence of actions and their impact on the duration of the technological cycle have been analyzed. The application of this method of calculation for technological operations of ink shift is inefficient. The article [12] presents information technologies for construction of sub-models of six-pole components for informational simulation of multi-mass mechanical systems. The developed sub-models of components of mechanical systems simplify the computer simulation of mechanical systems, and allow to model complex mechanical systems of web and sheet multicolor printing presses. The process of ink combination has not been researched in this paper.

Models of ink shift are based on the model of deformation of movable tape section and under certain assumptions [1, 3, 4, 13] that is why the process of ink shift is described inadequately which prevents the synthesis of ink combination system. From the above we have the problem of design and analyses of appropriate models of ink combinations in multi-ink rotary web printing presses.

The aim of the article is to design the information model of the ink combination process in multi-ink rotary web printing presses, at the action of major disturbances– elongation of the tape and the growth of the tape speed in the area.

PRESENTATION OF MAIN MATERIAL

The task of management is to achieve synchronous syn-phase tape movement and working units of the press (printing machine, folding unit, rotary knife). The position of the image of a new print, bend or cut with acceptable accuracy, must comply to the position with previously printed image on the tape. Necessary precision of ink combination is 0.05 ... 0.15 mm or less, and precision of tape cutting on a piece of sheet is 0.5 mm [14].

We should note that the length of tape from one technological operation to the other can reach 15–20 m, and the speed of the tape in modern printing presses is 8–12 m/sec. Significant impact on the accuracy of technological operations is made by a cyclic change in tape tension at rolls unwinding of irregular shape. Therefore, there may be a shift of technological operations and its rapid accumulation, leading to deterioration in the quality of printed products. In printing presses that have low speed, the control and regulation of ink shift can be done by a printer visually, you can also have selective visual control and precision control depending entirely on the individual capabilities of the printer. It is important to monitor the inks shift when printing from roll to roll (packaging products, manufacturing of labels, etc.). Visual quality control is possible only with the presses at low speed.

Let us consider multi-ink PPM, the scheme of which is shown in Fig.1. Elastic paper tape moves and is gradually printed in printing sections. Control marks are printed at the end of prints in each printing unit. At steady regime at constant speed V and constant tension on the tape Fi we print marks with consecutive numbers $1,2, ... i$ with intervals (length of the print) $Lo = Vdt$. These control marks applied on different printing sections will be the same.

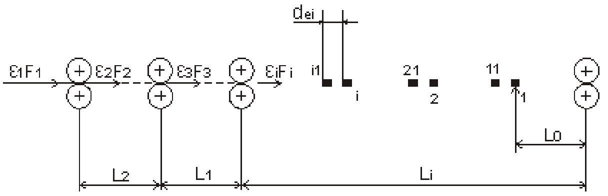

Fig. 1. Scheme of printing of control marks in multi-ink PPM

Let us assume that at a certain time there was an additional elastic deformation of the tape. For example, increasing the tape tension before (i-1) by the printing unit there is further deformation of the tape that will lead to a shift of marks as to their previous position. Then the change of the tape relative elongation is [14]:

$$\Delta\varepsilon(t) = \frac{dx_i}{L_0} = \frac{dx_i}{Vdt_i}. \quad (1)$$

where: $dx_i(t)$ – is an elementary shift of the tape.

Dividing the variables and integrating the equation (1), we obtain the dependence of the mark shift on the change of the tape deformation:

$$x_i(t) = V\int \Delta\varepsilon_i(t)dt. \quad (2)$$

Thus, we get the dependence of control mark shift on changing the tape deformation in the area.

Let us consider the shift of control marks printed on the tape on i-th and (i-1) -th printing units when changing the tape elongation at the input (i-1) -th printing unit. The expression of relative change through lengthening line is:

$$\varepsilon(t) = \frac{l_i(t) - l_{i-1}(t-T)}{L_i}, \quad (3)$$

where: $e_{i-1}(t), e_i(t)$ – is the elongation of the tape at the input and output of the area; L_i – is the distance (tape length) between printing units; $T_i = L_i/V_i$ – is the time of tape moving between printing units.

Here the tape elongation values $l_{i-1}(t-T_i)$ is taken in moments of the tape printing that is earlier than time Ti of the tape (marks) moving between the printing units.

Substituting (3) into (2), we obtain a control marks shift printed on adjacent printing devices:

$$x_{i/1-i} = 1/T_i 3\ [l_i(t) - l_{i-1}(t-T)]dt. \quad (4)$$

Thus we get the dependence of marks shift printed on adjacent printing sections from the tape elongation at the input and output areas.

We go to the operator record form, with (4) we have:

$$x_{i/i-1}(s) = 1/T_i s[l_i(s) - l_{i-1}(s)e^{-Ts}]. \quad (5)$$

Let us consider the case when there is the tape elongation li-1 (t) at the input area. This elongation of the tape at the input area will change the output elongation of the area li (t), which is described by the known dependence [4]:

$$\varepsilon(t) = \frac{l_{i-1}(t) - l_{i-1}(t-T)}{L_i}, \quad (6)$$

$$l_i(s) = \frac{1}{T_i s + 1} l_{i-1}(s).$$

After substituting into (5) and transformations we get:

$$x_{i/_{i-1}}(s) = \frac{1}{T_i s}\left[\frac{1}{T_i s + 1} - e^{Ts}\right] l_{i-1}(s). \quad (7)$$

Thus, we receive the dependence of marks shift from the tape elongation at the input area.

According to (7) in fig. 2 we can see the structural scheme of the model of marks (inks), printed on adjacent printing sections RRM.

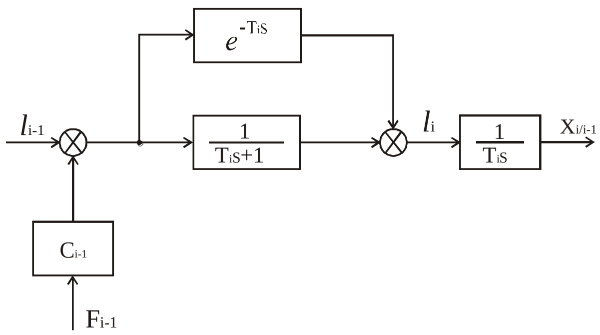

Fig. 2. Structural scheme of control marks shift

If the tape elongation at the input area is caused by the tension change, it will be determined as follows:

$$l_{i-1} = C_{i-1} \_ F_{i-1} \quad (8)$$

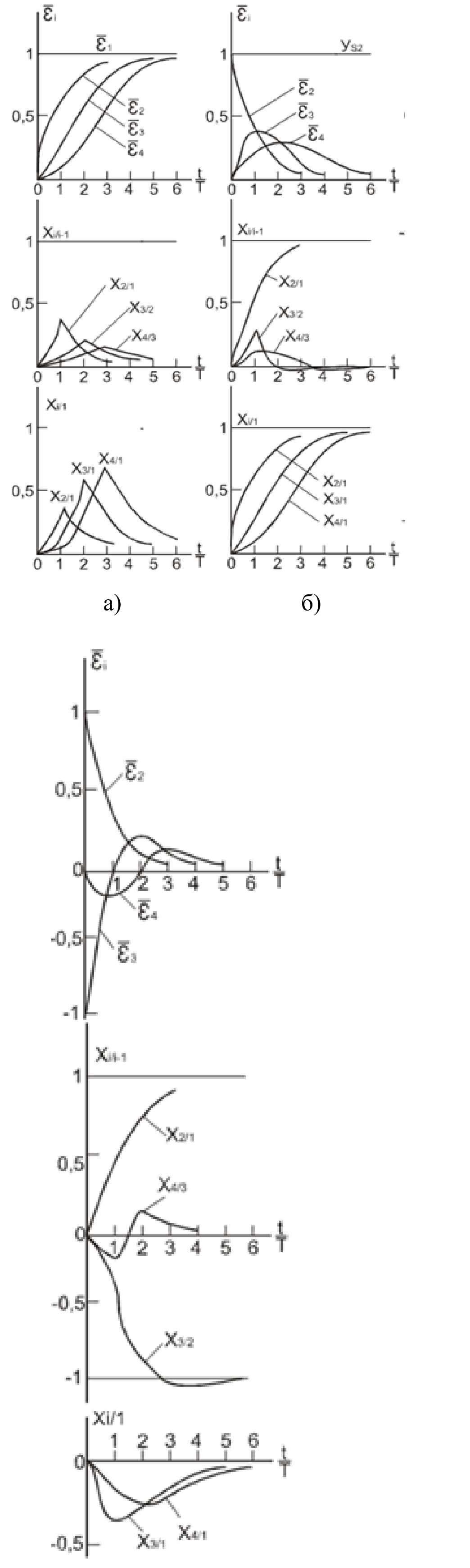

Fig. 3. Results of computer simulation of reaction of tape leading system to replace the tape tension (a) movement of register roller (б) phase change of cylinders (в)

This effect of the tension change on the inks shift is shown in fig. 2. According to (7) in fig. 3 transient parameters of ink shift when exposed to the input area of a single stepped elongation are constructed. It causes the change in state of elastic tapes, resulting in ink shift accelerating first and after the time *Ti* it is gradually reduced to zero. The dots mark the passage of a single print. The transition process ends by the time (3÷5) T_i. . During this time there may be a lack of printed matters. When full tape shift happened at the area and there is the tape stable deformation, there is a full ink combination.

On the basis of (7) in Fig. 4 the structural scheme of the model of control marks shift for multi-ink PPM is constructed. According to the structural scheme in Fig.3 we show the transient parameters in multi-ink PPM when exposed to the input of the first section of the unit of the tape stepped elongation. The inks shift depends on the base, in relation to which the displacement is measured. When comparing each subsequent ink with the previous (*x2 / 1, x3 / 2, x4 / 3*) the maximum value of the displacement decreases with increasing number of inks (sections).

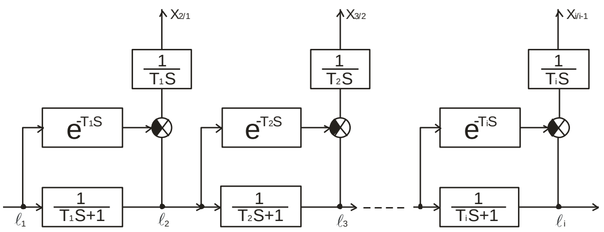

Fig. 4. Structural scheme of the model of ink shift in multi-ink printing press

If we measure the shift of all inks relatively to the first which is adopted as the base, ink shift increases with increasing number of inks (Fig. 3).

For the ink combination used in RRM we use a register roller that creates a regulatory effect on ink shift. [15-17] The scheme of the tape area with a register roller is shown in fig. 5. With regulatory action of the register roller l_{pi} we make the ink combination only on the regulated area of the tape.

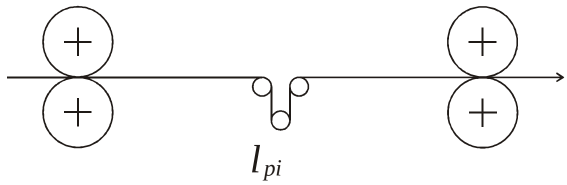

Fig. 5. Scheme of the tape with register roller

Moving of the register roller causes instant increase (decrease) of tape elongation in the same area, which gradually decreases due to the replacement of tapes and returns to the steady mode. Dependence of tape elongation at the end of the register roller movement (regulatory action) in images:

$$l_i(s) = \frac{T_i s}{T_i s + 1} l_{ip}(s). \quad (9)$$

where: l_{pi} – is the tape moving in the area, caused by the movement of the register roller.

Basing on (7) we can determine the ink shift caused by the movement of the register roller:

$$x_{i/i-1} = \frac{1}{T_i s} \cdot \frac{T_i s}{T_i s + 1} l_{pi}(s). \qquad (10)$$

After reduction we will have:

$$x_{i/i-1} = \frac{1}{T_i s + 1} l_{pi}(s). \qquad (11)$$

Thus, during the regulatory action of the register roller the gradual ink combination on a regulated area for the same amount is carried out.

Basing on the analysis of (11) we conclude that the inks shift process in the area regarding the regulatory action of the register roller is the inertia object of the first order.

The change of the tape elongation $l_i(s)$ (9), caused by the movement of the register roller, leads to a gradual fading impact of the inks shift in these areas.

Basing on previous structural scheme and (9) and (10) in Fig. 6 we constructed the structural scheme of the model of inks shift with a regulating influence of the register roller for four-section web printing press.

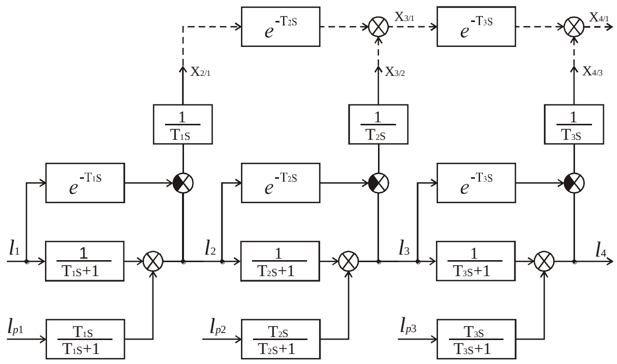

Fig. 6. Structural scheme of the information model of ink shift with a regulating influence of the register roller for four-section web printing press

The regulatory action for ink combination can be done with phase change of plate cylinders, which causes ink shift $l_{\phi i}$. The reaction of the tape area on the regulatory action is similar as in the regulation of the movement of the register roller. The shift of plate cylinders $l_{\phi i}$ will be similar (11). But the phase change of the plate cylinder simultaneously leads to similar ink shift of the opposite sign in the next area. This side effect of the regulating phase change of the plate cylinder is a negative phenomenon. This side effect can be levelled by additional regulation of the following plate cylinder. The impact of the phase displacement on the third area is due to additional deformation. Therefore, the phase change of the plate cylinder creates a permanent effect on the third section. The ink shift in this area is fading over time.

Fig. 7 presents the structural scheme of the model of ink shift with a regulating action of the phase of the plate cylinder [18-20].

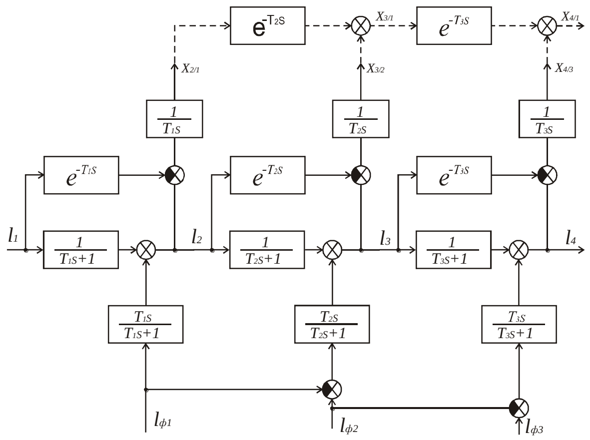

Fig. 7. Structural scheme of the information model of ink shift with a regulating action of the phase of the plate cylinder

The ink combination in multi-ink PPM can be seen in relative position of control marks on the tape. Thus, there are two basic ways to determine the ink shift (Fig. 8):

• ink shift of the following ink relatively to the previous one – $x_{i/i-1}$,

• ink shift of all the following relatively to the first ink, which is adopted as basic $x_{i/1}$.

The ink shift of the i-th ink relatively to the first one – $x_{i/1}$ is determined by summing of shifts at all the previous sections, taking into account the transporting time (transportation) of printed tape to the examining section:

$$x_{i/1}(t) = x_{i/i-1}(t) + x_{i-1/i}(t - T_i),$$
$$x_{i-1/1}(t) = x_{i-1/i-2}(t - T_i) + x_{i-2/i}(t - T_i - T_{i-1}). \qquad (12)$$

The structural schemes in Fig.6 and Fig.7 present the models of ink shift relatively to the first one $x_{i/1}$ shown as a dotted line.

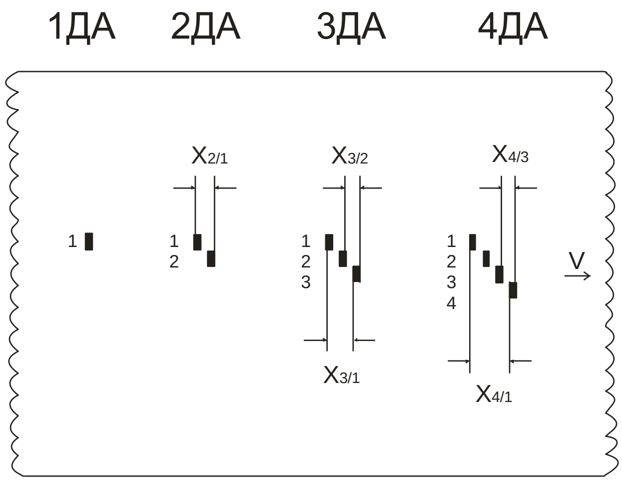

Fig. 8. Scheme of ink shift

Designed structural schemes of models of ink shift is the basis for a broad study of tape-driven systems of web printing presses under the influence of various disturbances and for the calculation and design of systems of automatic ink combination.

The generalized functional scheme of the regulation system of ink combination is shown in fig. 9. The object of the regulation OR is a tape area that is printed gradually in the printing section PS. Together with a print we print the control marks of the corresponding ink. Control marks are printed on the tape areas to be cut or bended.

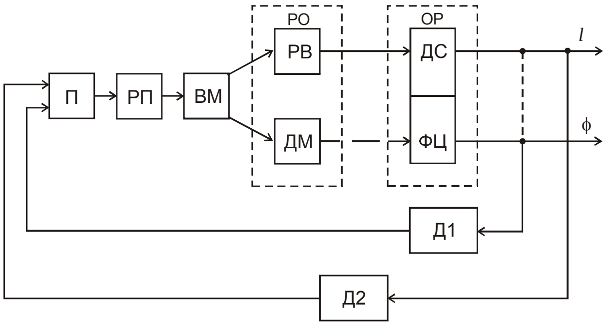

Fig.9. Generalized functional scheme of ink combination

Ink combination is measured by sensors D1 and D2, signals of which are fed to the input of the converter-amplifier P, where it is reinforced, formed and fed to the input of the reverse power amplifier PP, which takes control u to the input of the executive engine VM of the system. The latter moves the regulator unit RU of the system, which acts directly on the object with acceptable error combines inks coated on the adjacent sections.

CONCLUSIONS

1. Ink combination is achieved by the coordination of technological operations speed with the movement of the tape through the working units providing syn-phase of their movements.

2. Using the proposed structural scheme of the model of control marks combination (inks) printed at adjacent printing units PPM we get the dependence describing mark shift from changes of tape deformation at adjacent printing units (7).

3. Using the structural scheme of the model of ink shift we have researched the possibility of using the regulatory action of the register roller and phase of plate cylinders for ink combination in four sectional web printing press. On this basis, we have developed a functional scheme of the automatic control system of ink combination, in which ink shift is determined by the marks on the tape and the regulatory action is carried out by the register roller.

The results can be used in the synthesis of systems for automatic ink shift in multi-ink web printing presses.

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РАЗРАБОТКА ИНФОРМАЦИОННОЙ МОДЕЛИ ПРОЦЕССА СОВМЕЩЕНИЯ КРАСОК НА МНОГОКРАСОЧНЫХ РУЛОННЫХ РОТАЦИОННЫХ МАШИН

Анотация. Рассматривается построение информационной модели процесса совмещения красок на многокрасочных рулонных ротационных печатных машинах, вызванное изменением удлинение и приростом скорости на отдельных участках ленты. Проведен анализ системы автоматического регулирования совмещения красок. Исследованы параметры систем натяжения ленты рулонных ротационных машинах (РРМ) с использованием средств среды MATLAB для различных методов совмещения технологических операций, выполненных на ленте. Предложено информационные модели для автоматического контроля совмещения красок. Представлены результаты компьютерного симулирования.

Ключевые слова рулонная ротационная машина,информационная модель, подвижный ленточный материал, совмещение операций, компьютерное симулирование.