Definition of Quality Criteria of the Technological Process of Narrow Web UV-Printing

ABSTRACT

The application of Narrow Web UV-flexographic printing has several advantages compared with offset printing. In particular, they are the lack of the operation of water-ink balance setting in the technological process, the ability to print on a wide range of materials and so on. Though the imprint quality is clearly based on standards in offset printing, there are no clearly indicated requirements for Narrow Web UV flexographic printing. The absence of such requirements on quality parameters of the technological process of Narrow Web UV-Printing predetermined conducting its analysis with the help of expert surveys.

KEY WORDS
flexography, narrow web UV-Printing, expert, quality, fuzzy sets

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Introduction

Over the last decade there has been a transition tendency of label products manufacturers from offset printing to Narrow Web flexographic printing. This is due to new possibilities of imprints design "in line", the manufactures' desire to reduce production costs, to respond effectively to market demands and to provide small circulation, to reduce capital and maintenance costs for printing presses (Dorofeev, 1998; Katz, 2009; Parrish, 2010). The technological process of printing can be seen as a set of elements that are in certain relationships and connections with each other, they interact with each other and form certain integrity – the system. To get qualitative imprints it is necessary to achieve consistency between its elements, their interaction ensures the proper technological process of printing. The products quality of offset, gravure, screen, and flexographic printing is based on ISO 2846 (chapter 1-7). Unfortunately, the standard has no requirements for flexographic printing on a wide range of materials using UV-inks.

We have carried out this work to understand the influence importance of the technological system elements on the quality of UV-flexographic printing of labels on Narrow Web flexographic presses.

Methodology and results

To investigate the operations and technological processes the Analytic Hierarchy Process of T. Saaty is widely used (Saaty, 1980; Saaty, 1991), which solves the problem of multi-choice alternatives and the method based on fuzzy set theory (Baranov and

Ptuškin, 2004; Zaičenko, 2006). Such element of analysis, as the expert survey in a particular direction by using the developed questionnaire is widely used.

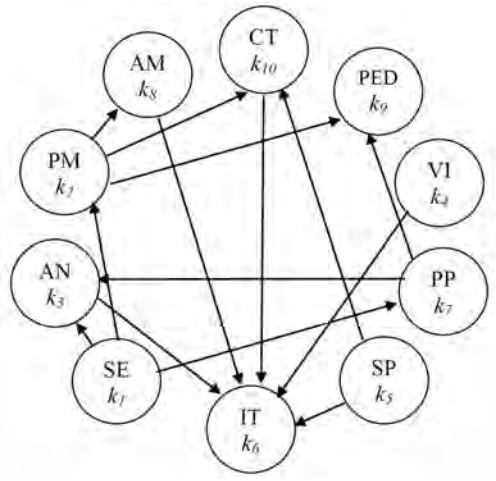
The survey was carried out in two stages. In the first stage, the experts were asked to specify the criteria which influence the quality of label UV-flexo printing on Narrow Web flexographic presses. Twenty-eight researchers in the field, technologists and operators of different UV-flexo printing companies were assesed as experts.

In the first stage, the experts proposed the criteria, often mentioned criteria we have selected:

k_1- the complexity of the label plot (SE);
k_2 – the type of the printing material (PM);
k_3 – the type and parameters of the anilox roller (AN)
k_4 – the optimum viscosity of UV-inks (VI);
k_5 – the printing speed (SP);
k_6 – the nature of ink transfer (IT);
k_7 – the type and parameters of the printing plate (PP);
k_8 – the acclimatization of the printing material (AM);
k_9 – the deformation of the printing elements (dot gain) (PED);
k_{10} – the surface treatment (corona discharge) (CT).

In the second stage, the experts were proposed a questionnaire for assessing the importance of each criterion. The set of such criteria can form a set K = $\{k_1, k_2, ..., k_n\}$, from which ten key criteria were selected. The subset of the selected criteria K_1 and the possible interconnections between them will be shown in the form of a directed graph (Figure 1).

We will place the elements of the subsets K_1 in the vertices of the graph, and the arcs will connect the adjacent vertices (k_i, k_j) for which we specified the connection that points to the dependence of the criterion ki from the criterion kj. For example, selection of the anilox roller depends on the complexity of the plot of the printing products and the lineature of the printing plate.



» **Figure 1:** *The graph of connections between the criteria of Narrow Web UV-Printing*

On the basis of the given graph we design the binary reachability matrix, the construction of which is to fill in the table in which the elements of the binary system are defined as follows:

$$m_{i,j} = \begin{cases} 1, \text{ if there is a directed edge from node to node } j \\ 0, \text{ in another case} \end{cases} \quad (1)$$

	k_1	k_2	k_3	k_4	k_5	k_6	k_7	k_8	k_9	k_{10}
k_1	1	1	1	0	0	1	1	1	1	1
k_2	0	1	0	0	0	1	0	1	1	1
k_3	0	0	1	0	0	1	0	0	0	0
k_4	0	0	0	1	0	1	0	0	0	0
k_5	0	0	0	0	1	1	0	0	0	1
k_6	0	0	0	0	0	1	0	0	0	0
k_7	0	0	1	0	0	1	1	0	1	0
k_8	0	0	0	0	0	1	0	1	0	0
k_9	0	0	0	0	0	0	0	0	1	0
k_{10}	0	0	0	0	0	1	0	0	0	1

The vertex k_j is reached from the vertex k_i if the directed graph (Figure 1) has a path that leads from the vertex k_j to the vertex k_i (in this case, the vertex is reached).

We assume that the subset of such vertices is S (k_i), and the vertex k_j is the predecessor of the vertex k_i, when reaching k_i from the vertex k_j. The subset of the predecessors' vertices is denoted as P (k_i).

The intersection of the subsets of the reached vertices and the predecessors' vertices is denoted as

$$S(k_i) \cap P(k_i) = R(k_i) \quad (2)$$

it defines a hierarchical level of the criteria priority that corresponds to these vertices. This additional condition must be taken into consideration: P (k_i) = R (k_i).

When the above mentioned actions are fulfilled we get the first level of the criteria hierarchy. We build Table 1 to find out its definition. Table 1 shows that the subset S (k_i) is the numbers of individual elements of corresponding matrix lines, the subset P (k_i) is the numbers of individual elements of the matrix column, and the subset of S (k_i) ∩ P (k_i) is the logical intersection of the elements of the subsets of S (k_i) and P (k_i).

The equality P (k_i) = R (k_i), i.e. the coincidence of the numbers of the criteria in the third and fourth columns is performed for the criteria k_1 (the complexity of the labels plot), k_4 (the ink viscosity), k_5 (the printing speed), which are the criteria of the first level of the hierarchy- the level of the biggest priority influence on Narrow-Web printing.

According to the structure method [4, 5] we delete the lines 1, 4, 5 (criteria k_1, k_4 and k_5) from Table 1, we cross out numbers 1, 4, 5 from the other lines and we obtain Table 2, which we use to determine the second level of the hierarchy.

In Table 2 the equality P (k_i) = R (k_i) is performed for the criterion k_2 (the type of printing material) – the second level of hierarchy. Following the previous algorithm of actions we obtain the criteria k_8,

k_{10}, k_7 for the third level 3, the criteria k_3, k_9 for the fourth level, the criterion k_6 for the fifth level.

Table 1
Iterative analysis of the reachability matrix

i	$S(k_i)$	$P(k_i)$	$S(k_i) \cap P(k_i)$
1	1,2,3,6,7,8,9,10	1.08	1
2	2,6,7,8,9,10	1.21	2
3	3,6	1.08	3
4	4,6	0.95	4
5	5,6,10	1.08	5
6	6	1.29	6
7	3,6,7,9	1.08	7
8	6,8	1,2,5,8	8
9	9	1,2,7,9	9
10	6,10	1,2,5,10	10

Table 2
The second iterative analysis of binary reachability matrix

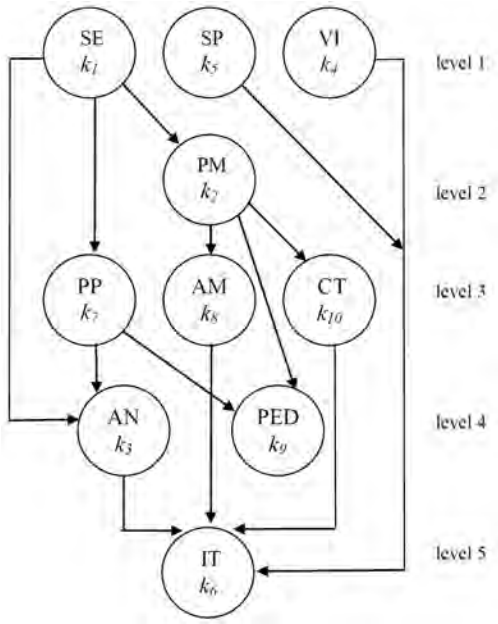
i	$S(k_i)$	$P(k_i)$	$S(k_i) \cap P(k_i)$
1	1,2,3,6,7,8,9,10	1.08	1
2	2,6,7,8,9,10	1.21	2
3	3,6	1.08	3
4	4,6	0.95	4
5	5,6,10	1.08	5
6	6	1.29	6
7	3,6,7,9	1.08	7
8	6,8	1,2,5,8	8
9	9	1,2,7,9	9
10	6,10	1,2,5,10	10

According to the results of the analysis we have built the hierarchy criteria model of the influence on Narrow-Web flexographic UV printing (Figure 2).

As a result of the research we have carried out the simulation (we have obtained the directed graph) and we have sorted out the criteria by priority of labels quality of Narrow-Web flexographic printing using modern methods of system analysis, the system of graph theory and matrix analysis.

In the second stage of the survey the expert is proposed to answer the following questions:

1. What impact will the complexity of the printed label have on the product quality?
2. What impact will the transition from coated paper to polymer materials have on the labels quality?
3. What impact will the increase of anilox resolution have on the labels quality?
4. What impact will the optimization of UV-inks viscosity have on the labels quality?
5. What impact will the optimization of printing speed have on the labels quality?
6. What impact will the optimization of UV-inks transfer have on the labels quality?
7. What impact will the increase of flexographic plate resolution have on the labels quality?
8. What impact will the deformation of printing elements have on the labels quality?
9. What impact will the corona treatment have on the labels quality?
10. What impact will the acclimatization of the printed material have on the labels quality?



» **Figure 2:** *The hierarchy criteria model of the influence on Narrow Web UV-Printing*

As the expert survey data in evaluating quality criteria are based primarily on fuzzy interpretation we considered it appropriate to apply the analysis algorithm of questionnaire results, which is based on the theory of fuzzy sets.

The ten experts is proposed to give each such assessment a confidence level that the selected quantitative assessment is correct. The confidence level can be quantitatively characterized by the verbal-numerical scale of Harrington which is shown below (Table 3).

Table 3
The scale of Harrington [5]

Confidence level	Value
very high	0.8 – 1,0
high	0,64 – 0,8
average	0,37 – 0,64
low	0,20 – 0,37
very low	0,0 – 0,20

One of the possible answers to the question: "What impact will the corona treatment have on the labels quality?" is shown in Table 4.

Table 4
The answer to the given question

Options	Possible values, %				
	0	25	50	75	100
It will not have any influence					
It will be slightly improved					
It will be improved					
It will be considerably improved	0	0,3	0,6	0,8	1,0
It will be greatly improved					

According to Table 4 membership function is:

$$\mu(u) = [0; 0,3; 0,6; 0,8; 1] \quad (3)$$

The given example in the table indicates the following:

- The expert chose the answer "It will be considerably improved"
- It is likely to improve the quality by 100% (confidence level 1,0)
- There is slightly less confidence (0,8) that the quality will improve by 75%.

The answers to the i-th question are put in the general Table 5. If the level of the experts competence is the same, the overall fuzzy assessment will be received at the intersection of fuzzy sets that are the answers of the respondents. The function quantifies this assessment in accordance with the rule of intersection of fuzzy sets (Zaičenko, 2006).

Table 5
The experts answer to the given question

Experts	Possible values, %				
	0	25	50	75	100
1	0	0,3	0,6	0,8	1,0
2	0	0	1,0	0,8	0,6
3	0	0,8	1,0	0,8	0,7
4	0	0,6	0,8	1,0	0,8
5	0	0,5	1,0	0,6	0,3
6	0	0	0	0,8	1,0
7	0	0,2	0,6	0,8	1,0
8	0	0,8	1,0	1,0	0,8
9	0	0,6	0,7	1,0	0,8
10	0	0,4	0,7	0,8	1,0

For example, the members of the expert group of 10 people responded to the above-mentioned question in a fuzzy set L with the membership function μ:

L_1 = 0/0+0,3/25+0,6/50+0,8/75+1/100, $\mu_1(u)$ = [0; 0,3; 0,6; 0,8; 1];
L_2 = 0/0+0/25+1/50+0,8/75+0,6/100, $\mu_2(u)$ = [0; 0; 1; 0,8; 0,6];
L_3 = 0/0+0,8/25+1/50+0,8/75+0,7/100, $\mu_3(u)$ = [0; 0,8; 1; 0,8; 0,7];
L_4 = 0/0+0,6/25+0,8/50+1/75+0,8/100, $\mu_4(u)$ = [0; 0,6; 0,8; 1; 0,8];
L_5 = 0/0+0/25+1/50+0,6/75+0,3/100, $\mu_5(u)$ = [0; 0; 1; 0,6; 0,3];
L_6 = 0/0+0/25+0/50+0,8/75+1/100, $\mu_6(u)$ = [0; 0; 0; 0,8; 1];
L_7 = 0/0+0,2/25+0,6/50+0,8/75+1/100, $\mu_7(u)$ = [0; 0,2; 0,6; 0,8; 1];
L_8 = 0/0+0,8/25+1/50+1/75+0,8/100, $\mu_8(u)$ = [0; 0,8; 1; 1; 0,8];
L_9 = 0/0+0,6/25+0,7/50+1/75+0,8/100, $\mu_9(u)$ = [0; 0,6; 0,7; 1; 0,8];
L_{10} = 0/0+0,4/25+0,7/50+0,8/75+1/100, $\mu_{10}(u)$ = [0; 0,4; 0,7; 0,8; 1].

The functions of the generalized opinion are calculated by the formula:

$$M(U_i) = \min [(\mu_1(u_i), (\mu_2(u_i),..., (\mu_n(u_i)] \quad (4)$$

Accordingly, as the result, on the issue of the effect of film surface treatment by corona discharge, we obtain: [0; 0; 0; 0,6; 0,3]. The result of the expert survey is the maximum value of the function:

$$u^*_i = \arg\max \mu_i(u_i) \quad (5)$$

Accordingly, u* = 0,6, corresponding to a 75% improvement of the labels quality when processing the polymer films by corona treatment. We have analyzed the answers to other questions similarly (Table 6).

Table 6
The results of the survey

Question	The maximum value of the function ,u*				
	0	25	50	75	100
1	0	0	0,3	0,5	1,0
2	0	0,2	0,5	0,8	0,2
3	0	0	0,5	0,8	1,0
4	0	0	0	0,2	0,5
5	0	0	0,7	0,2	0
6	0	0	0,5	0	0
7	0	0	0	0,6	0,8
8	0	0	0,8	1,0	0
9	0	0	0	0,6	0,3
10	0	1,0	0,2	0	0

When conducting this survey we have found that the complexity of the printed products and the anilox resolution have the greatest importance among the criteria. Experts with confidently u* = 1 showed that these criteria improve the quality to 100%.

Conclusion

Thus, we can conclude from the results of this survey, which criteria will improve the quality UV flexographic printing of labels on Narrow Web flexographic presses. According to the hierarchy analysis method we have revealed that the following criteria have the highest priority: the complexity of the labels plot, the printing ink viscosity, the printing speed. In the second stage of the survey we have found out that the most essential criteria are the complexity of the labels plot and the parameters of the anilox roller. Experts showed with maximal confidently (u* = 1), that these criteria improve the quality up to 100 %. As you can see in these two cases, the very important criterion is the complexity of the labels plot. This importance is obvious, because it determines the selection of the parameters of photo-polymeric printing plate and the relevant anilox roller. The considered survey methodology and analysis will identify and predict the impact level of various elements of the technological system on the imprints quality received by Narrow Web UV flexographic presses. It can also be used to analyze other technological systems. Our next step in this analysis will be determining the impact of the experts' competence participating in the survey.

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