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COLOUR REPRODUCTION WITH DESIGN OF EXPERIMENTS

Johanyák, Z. C.

Abstract: *The critical point in the manufacture of metal-packing appliances is to produce the correct printing of the inscriptions and graphics in the colours expected by the customer. In the case when there are differences in colour, the product can be sold only at a reduced price, or cannot be sold at all. The process itself is not very complicated, but the result is influenced by a large number of parameters which should be "set up" optimally upon designed experiments.*

The success key of the process-optimisation based on experiment-methodology is the proper preparation work. This can be effectuated without thorough practical knowledge about the process itself, for example, with the aid of Shainin techniques, but the presence of the experience is able to reduce the amount of necessary resources. In what follows we will offer a survey about the most important theoretical and practical questions related to this problem.

Key words: *Design of Experiments, ANOVA, Taguchi method, S/N analysis*

1. COLOUR MEASURING

The light beams with different wavelength appears in our mind like different colours. The purpose of the colour measuring is to develop numbers, which correspond to our colour sensations. This problem is solved by the mixing of the additive colour stimulus.

The CIELAB colour measuring system (Fig. 1.) is standardized in Hungary. In this system the colour is represented by a point in a three dimensional coordinate system called chromatogram. The (a) axis contains the colours from green to red, the (b) axis is the blue – yellow transition and the (L) axis determine the saturation of the colour.

The colour stimulus difference between the x and y colour points is given by the following equation (1).

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \quad (1)$$

Customers select the colours of the printings from the

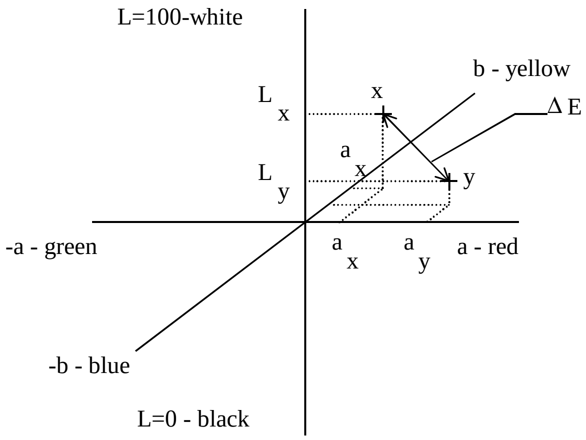

Fig. 1. The CIELAB system

ΔE	Qualification
0.0 – 0.5	imperceptible
0.5 – 1.5	scarely perceptible
1.5 – 3.0	perceptible
3.0 – 6.0	visible
6.0 – 12.0	great difference

Table 1. Qualification

Pantone scale which is the most widespread used method in printing industry and contains over 3000 colour patterns (samples).

The aim of the experiment is to reproduce perfectly the colours with the following identification: P485C, P471C, P351C because during printing of these colours arise the most of the quality problems.

2. QUALITY CHARACTERISTIC

During delivery the acceptance of the manufactured packing material is determined by the difference between the chosen colour pattern and the colour stimulus of the product, consequently ΔE is the chosen measure as quality characteristic to sign the difference between the two colours.

The purpose of the process optimalization is to decrease these values as low as possible, so the quality characteristic type is "the lowest the best".

Determination of the value of ΔE was carried out on a Gretag SPM 55 type spectrophotometer. This instrument works with one figure accuracy. Table 1. contains the classification of the different ΔE value intervals.

3. FACTORS

When designing the experiment the influencing process elements and parameters are referred to as factors whereas the connected positioning values are called levels.

The proper selection of these values require experience and professional practice for several years because it can decisively influence the result of the activity.

The factors can be classified into two groups (Jeschke, 1997). The factors which different level positioning do not rise any technical or economical difficulties can be considered controlled ones. On the contrary the noise factors are influencing ones which can not be adjusted or it's cost

A	colour type
B	print support colour
C	printing power
D	stamp in time
E	stamp in temperature
F	type of the outer coating system
G	stamp in time of the outer coating system
H	stamp in temperature of the outer coating system
I	layer thickness of the outer coating system
J	the thickness of the paint from the cylinder

Table 2. Controlled factors

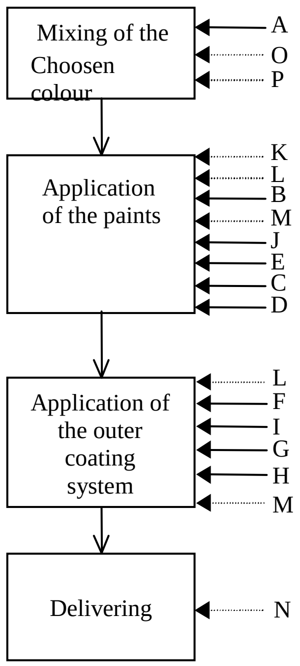

Fig.2. Colour reproduction process

exceed the expected profit.

On preparing (Table 2.) the experiment, ten controlled factors and six noise factors could be identified during the printing process. Decomposing the process in steps, in Fig. 2. you can see the different factors are effective.

The noise factors are represented by arrows with broken line while the arrows with continuous lines represents the controlled factors.

In the case of each factor three levels are settled.

4. EXPERIMENT DESIGN

The experiences related to metal printing allowed to select the influencing factors. The most adequate choice was to use a factorial design. The full factorial design, which can take all the possible interactions into account and which is the safest method, needs 3^{10}=531441 number of experiments that can not be realised practically (Cobb, 1998).

Based on the results, we came to the idea was the assumption that the interactions between the different factors can be neglected. That is why Taguchi $L_{27}(3^{13})$ orthogonal array was selected from all the methods dealing with simplification, so we can examine 13 factors on three levels without interactions with the help of 27 experimental settings. 81 experiments are needed having each setting three time. This can lead to a drastic decreasing of the resource demands. Neglecting the interactions has lead to the risk that the optimal parameters calculated from the results of the experiments do not show the real situation. In this case should be prepared such designs that make the evaluation of the formerly neglected interactions possible.

These results make loss of time and money, but based on experiences this risk could be shouldered and the results have proved the assumptions.

5. EVALUATION

The evaluation of the experimental results can be carried out by different methods. In our case because of repeated experiments we decided to use the signal/noise (S/N) analysis of Taguchi (Roy, 1996).

While the traditional analysis of variance (ANOVA) uses the average of the results obtained from repetitions, the signal/noise analysis takes into account the differences between each value too, and calculates the mean squared deviation (MSD)(2) and then using this, calculates the S/N ratio (3). Here n represents the number of values which belong to one adjustment type. The ANOVA carried out with the calculated S/N ratio completed with a simple effect analysis enable to pool those factors that are of no importance and to find such a combination of parameters that can solve the problem. This means that the signal and the variation of the values of the pooled factors do not have influence on the result.

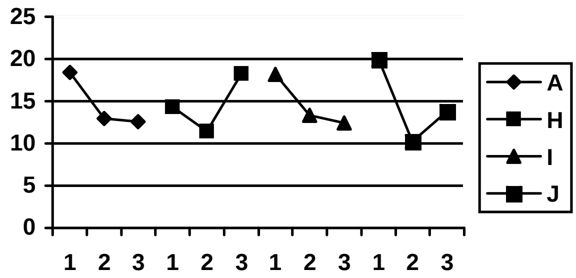

Fig. 3. Effect analysis

$$MSD = \frac{\sum_{i=1}^{n} \Delta E_i^2}{n} \quad (2)$$

$$S/N = -10 \cdot \log_{10}(MSD) \quad (3)$$

The pooling of the less important factors can be important from economical point of view, because it can happen that in the case of a factor the adjustment of the different levels needs expenditures of very different rates (Leist, 1996). If we can choose between three possible values to set and it has no significant influence on the result which one is selected we should decide on the cheaper solution.

The calculations showed that in the case of red colour the A, H, I and J (Fig. 3.) , in the case of green the A, G, H, I and J, while in the case of brown colour the H, I, and J factors have dominant effect (Johanyák, 1999).

6. CONTROL EXPERIMENTS

The control experiments allows to determine how well the optimal parameters were determined by calculations (Montgomery, 1996).

In the case of all the three colours the results showed improvement compared with the values before the process optimalization.

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Author: Zsolt Csaba JOHANYÁK. Senior Lecturer at Department of Information Sciences, College of Mechanical Engineering and Automation Kecskemét, Izsáki út 10., H-6000 Kecskemét, Hungary, Phone: 0036 76 516 325 Fax: 0036 76 516 399 E-mail: johanyak.csaba@gamf.kefo.hu, http://johanyak.hu