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ROTARY PRINTING: PASTE REDUCTION AND PASTE CALCULATION USING STATISTICAL ANALYSIS

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Abstract*. The pigment printing method is preferred because it is acceptable for all kinds of fiber types, suitable for sensitive fabrics, does not need to be washed after printing, and has good fastness. There are many factors affecting the consumption of printing paste in rotary screen printing. These factors include fabric structure, printing speed (m/min), bar size (mm), machine press, screen mesh number (holes/inch), colours of patterns, colour deepness and counter clearness, printing paste chemicals, and paste viscosity. The complicated calculation of the printing paste system is made even more difficult by numerous parameters. For this reason, it is difficult to prepare the correct amount of printing paste, which is determined by the operator's experience. This situation increases the amount of waste in the water as well as the overall cost. In order to reduce the waste of printing paste, this study aims to develop a new method that performs calculations using algorithms instead of experience-based systems. In order to achieve this, a data pool was first created by using production data from the printing department, and close to 600 records were used in this study. The amount of paste consumed in a 1 m^2 area of fabric was calculated using the data obtained. In short, it will be called the consumption factor. To evaluate the variance of this factor in relation to machine parameters, one-way anova and Dunn's tests were used. According to the findings, bar size and mesh count have a significant impact on paste consumption. It has been shown that machine speed and pressure have an indirect impact on printing paste consumption through other parameters. With the new system, the printing paste calculation accuracy rate was evaluated in 3 ways: as "saved recipes", "underweight recipes" and "overweight recipes". The accuracy rates for "saved recipes," "underweight recipes", and "overweight recipes" were respectively 66%, 19%, and 15%. The amount of waste paste rate has been reduced from 23% to 12%. When the cost of the savings ratio is computed, it is found that $ 1128 can be saved on the price of printing paste and dyestuff.*

Keywords: *Rotary printing, pigment printing, print paste optimisation, sustainability, waste reduction.*

1. INTRODUCTION

Textile printing is the branch of the textile wet processing industry is becoming increasingly popular for all fibers varieties of fabrics as well as garments [1]. Pigment printing is the cheapest way of rotary screen printing and it is possible on all types of fabric. Other advantages include faster manufacture, low cost, and lack of steam and washing. However, pigment rotary printing has some disadvantages. These include high printing costs for prints shorter than 2000 meters, machine color restrictions, a prolonged preparation process, and others [2]. The complexity of printing paste consumption is another big drawback. This makes it more difficult to calculate the proper amount of printing paste. Also, printing paste is calculated by skilled operator in the printing department. The prediction of the optimal printing paste, no matter how skilled, is low since printing paste calculation depends on numerous parameters. The consequence is rise in overall costs, waste water, and waste paste. Among the critical sustainability challenges are waste management and the use of resources.

Celikbilek (1999), determined the amount of printing paste utilized per unit area in rotary printing under laboratory conditions by altering the printing parameters. For the printing process, 10x10 cm fabric samples were used. The consumption amount in 1 m^2 was determined by multiplying by 100. Based on the findings,

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an algorithm was developed and integrated into the ERP software with information on color percentages, pattern size, and fabric [3].

In their study Lomas and Short (1999), the effects of changing screen printing parameters in rotary and flat-screen printing on the amount of print paste consumed were examined. For this study, there are 5 different kinds of fabric used; 100% cotton (plain), 100% cotton (satin), polyester/cotton (satin), polyester/cotton (plain), 100% (knitted) polyester, stitch bond polyester/viscose (nonwoven). The consumption factor was determined after 1000 m^2 of fabric was printed with a 100% coverage screen on a variety of substrates. As a result, different fabric types, increasing bar size and lower mesh counts increases the consumption of printing paste. Different magnet pressures has no significant effect on consumption. A paste calculation formulation was developed with a consumption factor, the fabric's width and length (in meters and kilometers), a percentage of the screen's open mesh, and a costant amount of waste print paste (kg) [4].

Textile rotary printing departments usually calculate the printing paste based on the experience of the workers. A limited number of studies have been found in the literature on the reduction of rotary printing paste waste. The purpose of this research is to develop a new calculation technique that uses algorithms rather than experience-based systems to reduce the waste of printing paste.

2. EXPERIMENTAL PART

In this study, plain weave fabrics used as sheet were used for calculation. Fabrics with a blending ratio of 100 % cotton, 65 % polyester/35 % cotton, 70 % polyester/30 % cotton, ranforce, akfil, and flannel fabrics, and GMS of 250 g/m^2 or below, are used. Machine speed, bar size, magnet pressure and screen mesh count were chosen as determining factors for the printing paste calculation. In the experiment, the viscosity of the printing paste remained constant. Parameters details are shown in Table 1. Reggiani UNICA240/12/12 model with 12 colour was used for printing. A database has been created with data on productions that are over 2000 meters. Machine printing parameters, prepared paste amount, waste paste amount, pattern size, colour screen open area percentages, width and length of fabric data were collected from pigment printing department. The statistical anova tests were performed with the R software.

Table 1

Details of the machine parameters used in the calculation of the printing paste

Bar Size (mm)	Screen Mesh Count (holes/inch)	Magnet Pressure	Machine Speed (m/min)
12	80	Min:30	Min:25
16	125	⋮	⋮
20	155	Max:80	Max:60

The study was carried out under four headings, which is given below, respectively.

1. The determined parameters were used to create a data pool, and the data were then extracted for statistical analysis.
2. Utilizing the paste value consumed during manufacturing and the fabric printing area (m^2), consumption factors (gr/m^2) were determined in accordance with the percentages of the color screen open area (%). The constant waste (wastage in the screen and pump) amount for printing paste was taken at 7.5 kg.
3. According to machine characteristics and color screen open area (%), consumption factor values are optimized. The required paste amount in production can be calculated using algorithms that are remarkably accurate.
4. Pigment printing paste calculation algorithms has been added to the ERP system.

3. RESULTS AND DISCUSSION

3.1. Statistical analysis results of pigment printing paste consumption factors

In data pool, almost 900 data were gathered, and they were categorized based on the amount of prepared paste and waste paste, pattern, fabric information and printing machine parameters. Variants with common dyes and different construction fabrics (exp; muslin, twill etc.) which has small number of printing data were removed from data pool and close 600 data were used in this study. Printing parameters change

according to each pattern, and the lowest and highest printing settings are rarely used. Furthermore, as the average print paste consumption factors are rather irregular in color screen open area 2.5% and below. Because of these reasons, it was possible to work on anova analysis with 286 data. In Table 2, average of printing paste consumption factors are given.

Table 2

Average consumption factor values according to independent variables

	Screen Mesh Count (hole/inch)			**Pressure**			
Machine Sub-Parameters	**80**	**125**	**155**	**40**	**50**	**60**	**70**
Number of Data	16	233	37	18	149	88	31
Average Consumption Factor (gr/m^2)	117	106	105	107	107	106	106
	Machine Speed (m/min)					**Bar Size (mm)**	
Machine Sub-Parameters	**35**	**40**	**45**	**50**	**55**	**12**	**16**
Number of Data	28	108	59	84	7	121	165
Average Consumption Factor (gr/m^2)	108	104	107	103	94.6	101	111

Table 3

One-way anova results of consumption factor according to machine parameters

	Df	**Sum Sq**	**Mean Sq**	**F value**	**Pr(>F)**
Machine Speed	4	1993	498	1.441	0.2209
Pressure	3	543	181	0.523	0.6666
Bar Size	1	7130	7130	20.617	8.73e-06 ***
Screen Mesh Count	2	2661	1331	3.848	0.0226 *
Machine Speed-Pressure	7	4733	676	1.955	0.0617 *
Machine Speed-Bar Size	3	1377	459	1.327	0.2661
Pressure-Bar Size	3	1797	599	1.732	0.1609
Machine Speed-Screen Mesh Count	3	3128	1043	3.015	0.0306 *
Pressure-Screen Mesh Count	1	1049	1049	3.033	0.0828
Bar Size-Screen Mesh Count	2	1123	561	1.623	0.1993
Machine Speed-Pressure-Bar Size	5	1385	277	0.801	0.5498
Machine Speed-Bar Size-Screen Mesh Count	1	502	502	1.452	0.2294
Residuals	250	86452	346		

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

When the Shapiro test is used on the data, the data displays a distribution that is almost normal. The p-value result is 0,0386. One-way Anova test was applied because the data had a nearly normal distribution. One-way Anova test results are shown in Table 3. According to the results, it can be observed that changing the parameters for bar size and mesh number has a 0.05 significance level impact on paste consumption. Machine speed and pressure have no significant effect on paste consumption. Machine speed has indirect effect on paste consumption when combined with other parameters. Due to the large number of independent sub-variables and the lack of sufficient data, Dunn's test was applied to make pairwise comparisons. Dunn's test result and Table 2 shows that the print paste consumption is higher with a 16 mm bar size than with a 12 mm bar size. As the mesh number increases, the paste consumption decreases. However, the consumption of 155 mesh number did not create a significant difference with 125. At machine speeds of 35 m/min and below, it is shown that the printing paste consumption rises. The results obtained are in accordance with the literature.

The machine parameters' paste consumption statistical results were taken into account when formulating the algorithms. In the engraving process, the mesh count and open screen area percentage were engraved on the rotary screen in accordance with the print pattern. Because of this, the color screen open area and mesh count cannot be changed. The color screen open area is the first step in the algorithm, and it divides the methods into five groups. In the second stage, the algorithm is run using three different screen mesh counts. The parameters for the following procedures are chosen in accordance with the fabric's structure and design. These parameters are machine speed, pressure, and bar size. Print paste calculation formula is

shown (1) equation. Pattern area, fabric print area units are m^2. Consumption factor unit is gr/m^2 and constant print waste unit is kg.

$$\text{Paste(kg)} = \frac{\left(\frac{\%\,\text{ColorOpenarea} * \text{Pattern area} * \text{fabric print area}}{\text{Pattern area}}\right)}{100} * \frac{\text{ConsumptionFactor}}{1000} + \text{Constant Print waste} \cong \text{round result with 5} \quad (1)$$

Table 4

Dunn's test results of machine speed parameter on consumption factor

Dependent Variable	Group1	Group2	N1	N2	p-value	p.adj	p.adj. signif.
Consumption Factor	35	40	28	108	0.351	1	ns
Consumption Factor	35	45	28	59	0.789	1	ns
Consumption Factor	35	50	28	84	0.322	1	ns
Consumption Factor	35	55	28	7	0.0672	0.672	ns
Consumption Factor	40	45	108	59	0.399	1	ns
Consumption Factor	40	50	108	84	0.899	1	ns
Consumption Factor	40	55	108	7	0.140	1	ns
Consumption Factor	45	50	29	84	0.362	1	ns
Consumption Factor	45	55	59	7	0.0749	0.749	ns
Consumption Factor	50	55	84	7	0.157	1	ns

Table 5

Dunn's test results of bar size parameter on consumption factor

Dependent Variable	Group1	Group2	N1	N2	p-value	p.adj	p.adj. signif.
Consumption Factor	12	16	121	165	0.000157	0.000157	***

Table 6

Dunn's test results of pressure parameter on consumption factor

Dependent Variable	Group1	Group2	N1	N2	p-value	p.adj	p.adj. signif.
Consumption Factor	40	50	18	149	0.895	1	ns
Consumption Factor	40	60	18	88	0.868	1	ns
Consumption Factor	40	70	18	31	0.765	1	ns
Consumption Factor	50	60	149	88	0.941	1	ns
Consumption Factor	50	70	149	31	0.778	1	ns
Consumption Factor	60	70	88	31	0.828	1	ns

Table 7

Dunn's test results of pressure parameter on consumption factor

Dependent Variable	Group1	Group2	N1	N2	p-value	p.adj	p.adj. signif.
Consumption Factor	80	125	16	233	0.00672	0.0201	*
Consumption Factor	80	155	16	37	0.00901	0.00901	*
Consumption Factor	125	155	233	37	0.648	0.648	ns

3.2. Comparison of the consumption of pigment printing paste using the conventional method and the new method

The printing paste calculation screen in the ERP system is seen in Figure 1. When a fabric batch number is input into the ERP system, data for fabric information, pattern information, and template information is automatically obtained. Machine speed, pressure, and bar size information are entered manually in the ERP system. When the "Calculation" icon is clicked, the program estimates the approximate amount of paste required for each color in the pattern.

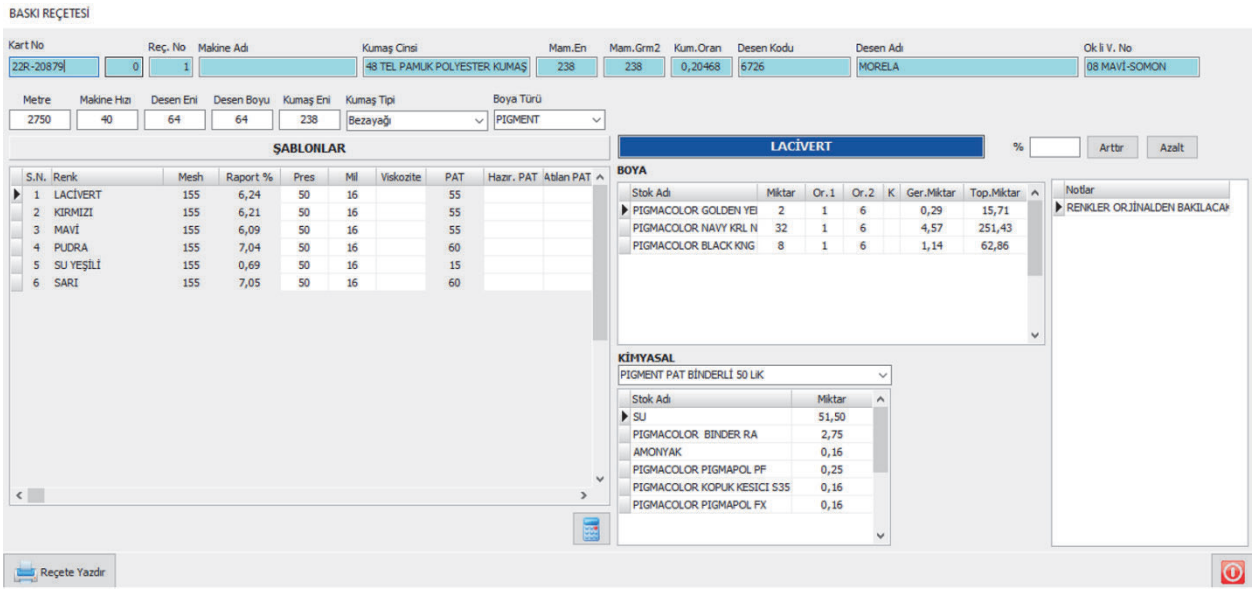


Figure 1. Printing paste calculation screen in the ERP system

Table 8

Evaluation of the new printing paste calculation method.

Color Screen Open Area (%)	Overweight Recipes	Underweight Recipes	Saved Recipes	Number Of Data	Savings (%)
0.01 – 0.8	1	12	70	83	84
0.8 – 1.5	4	15	47	66	72
1.5 – 2.5	6	18	47	71	66
2.5 – 6.0	12	6	112	130	82
6.0 – 100.0	68	60	116	244	46
Total	102	108	384	594	
Results (%)	15	19	66		

Results of the new calculation method evaluation are shown in Table 8. All data were calculated again using the new printing paste calculation method. The calculation method was evaluated in 3 ways. The accuracy rates for "saved recipes", "underweight recipes", and "overweight recipes" were respectively 66%, 19%, and 15%. As can be seen in Table 9, the new calculating method resulted in a 12% rate of waste paste amount. The amount of printing paste waste has been reduced by 49% as compared to conventional method. When the cost of the savings ratio is computed, it is found that $ 1128 can be saved on the price of printing paste and dyestuff.

Table 9

A comparison of the pigment printing paste calculation amounts using the old and new methods

Color Screen Open Area (%)	Conventional Method Total Prepared Paste (kg)	Total Paste Waste (kg)	New Method Total Prepare Paste (kg)	Total Paste Waste (kg)	Reduced Paste Waste (%)
0.01 – 0.8	2700	2014	1245	559	-72
0.8 – 1.5	2390	1358	1535	503	-63
1.5 – 2.5	2815	1334	2070	589	-56
2.5 – 6.0	7061	2739	5760	1438	-50
6.0 – 100.0	41877	5351	39780	3254	-39
Total	56843	12796	51745[1]	6520[2]	
Results (%)	Paste Waste (%)	23		12	-49

[1] The underweighed paste amount was added to the total amount of paste prepared theoretically.
[2] 15% of the theoretically calculated underweight paste amount was added to the waste paste amount.

4. CONCLUSIONS

Human experience-based systems can lead to serious issues in textile manufacturing facilities. In this study, a novel approach for calculating conventional pigment printing paste is proposed. It is predicted that by using this method, human factor mistakes will be minimized. This method's development made use of statistical data analysis. Calculating the printing paste is complicated by the fact that there are too many parameters involved. The data given in this study was completely obtained from the bulky production, and therefore, the accuracy rate remained at 66% due to the lack of sufficient data. In future studies, a saving rate of 85% and above is targeted. Other fabric constructions will be added to the printing paste computation. Finally, the calculating method's adaptability to dispersion and reactive printing will be studied.

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REFERENCES

[1] Solangi WH et al.: *Influence of binders and thickeners of pigment printing paste on light fastness and crocking fastness of the fabric*, *International Journal of Science and Research*, **3.** (2014); 5, pp.1024-33.
[2] Notermans J.: *Digital pigment printing: the eternal promise or a close reality?*, Available from https://blog.spgprints.com/digital-pigment-printing-promise-or-reality. Accessed: 2020-12-03
[3] Çelikbilek, A.: *Tekstil baskıcılığında hazırlanacak pat miktarının bir bilgisayar programı yardımıyla belirlenmesi* (Master's thesis, Uludağ Üniversitesi), (1999).
[4] Lomas M, Short IG: *Screen printing variables and their effect on print paste consumption. Coloration Technology*. **115**. (1999) Sep; (9):262-9.