(REFEREED RESEARCH)

DESIGN OF AN ULTRASONIC WASHING PROCESS AS AN AFTER-TREATMENT FOR DEVELOPING REACTIVE PRINTING QUALITY AND FASTNESS

REAKTİF BASKI KALİTESİNİ VE HASLIĞINI İYİLEŞTİRMEK İÇİN ARD İŞLEM OLARAK ULTRASONİK YIKAMA İŞLEMİNİN TASARIMI

Sevinç Ayşe ZALOĞLU[1], Gülay ÖZCAN[2*], Pınar ÜLKÜ[2], Buşra YILMAZ[2]

[1]*Istanbul Technical University, Department of Mechanical Engineering, Istanbul, Turkey*
[2]*Istanbul Technical University, Department of Textile Engineering, Istanbul, Turkey*

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ABSTRACT

In the textile industry, washing process after printing or dying is very costly for the companies because it needs more energy, water, chemical and time during the process. Eventhough more money is spent for washing, usually the obtained consequences like fastness, fabric strength are not satisfactory. It can be said that end product quality depends on the washing process even if previous processes which the fabric is treated until washing process is perfect. The technology used now for washing does not give the desired result in terms of quality and cost, and producers are waiting for a newly enhanced and designed process for washing. The main aim of this study is to propose a new washing process. This survey has been carried on by using industrial standards and international test methods related with washing and fabric quality. As a result, a new washing method will be proposed at the end of the studies.

Key Words: Reactive printing, Printing quality, Washing-off, Ultrasonic washing, After-treatment.

ÖZET

Tekstil sektöründe baskı ve boyadan sonra yapılan yıkama prosesleri, proses boyunca çok fazla enerji, su, kimyasal ve zaman tüketimi olduğundan firmalar için çok maliyetlidir. Fakat maliyetli olmasına rağmen yıkama sonrası elde edilen haslık sonuçları, kumaş mukavemeti vs. genellikle beklenildiği ve istenildiği gibi değildir. Bu bağlamda, son ürünün kalitesinin, yıkama prosesinden önceki tüm aşamalar mükemmel olsa da aslında yıkamanın verimliliğine bağlı olduğu söylenebilir. Günümüzde baskı ve boya sonrası yıkama için kullanılan teknoloji kalite ve maliyet açısından istenilen sonucu verememekte ve üreticiler yeni bir yıkama sisteminin tasarlanmasını ve geliştirilmesini beklemektedir. Bu çalışmanın ana amacı yeni bir yıkama prosesi önermektir. Bu doğrultuda, yapılan deneyler yıkama ve kumaş kalitesiyle ilgili uluslararası test metodları ve endüstriyel standartlar kullanılarak yürütülmüştür. Çalışma sonunda da yeni bir yıkama metodu önerilecektir.

Anahtar Kelimeler: Reaktif baskı, Baskı kalitesi, Yıkama, Ultrasonik yıkama, Ard işlem.

[*] **Corresponding Author:** Gülay Özcan, ozcangul@itu.edu.tr, Tel:+ 90 212 293 13 00 Fax:+90 212 249 17 67

1. INTRODUCTION

Textile printing is the most versatile and important of the methods used for introducing colour and design to textile fabrics. Considered analytically it is a process of bringing together a design idea, one or more colorants, and a textile substrate (usually a fabric), using a technique for applying the colorants with some precision. Several techniques (direct printing, resist printing and discharge printing) and colorants have been used (1).

Different processes have been developed for textile printing, depending on the kind of the fabric used (cellulosic, polyester, acrylic, protein...), on the nature of the dyestuff applied (reactive dye, vat dye...) and on the expected quality of the final product. The printing paste mainly contains the colorants and the thickeners (2). The printing paste undergoes high deformation rates and stresses and, consequently, marked changes in the rheological parameters occur such as viscosity drop and increased elasticity, which all together give the printing paste the capability to penetrate into the fabric

(3). After printing the fabric, the paste is dried to prevent accidental smearing of the print design and color migration. At this point, depending on the printing plant layout, the printed fabric may immediately go through the fixation process, or it may be held to go to fixation later. The type of colorant and production issues with the printing operation dictates the choice. The next step is fixation of the print color. For dyes, fixation normally incorporates an atmospheric steamer with specified moisture content and a nominal temperature of 212°F (100°C). With certain dyes, an auxiliary chemical may be necessary as an extra additive to the print paste. For example, for complete fixation, reactive dyes require additional alkali. In the case of vat dyes, reducing agents are necessary. For pigments on all fibers and disperse dyes for polyester or nylon, only high temperatures are necessary. The fixation equipment used can be a dry heat oven or super-heated steam. The key issue is reaching temperatures of approximately 350°F (177°C) to cure a synthetic pigment binder and as high as 400°F (205°C) for disperse dyes. In the case of dye prints, the printed fabric is thoroughly washed then dried after fixation. This step is necessary to remove the thickener, alkali, and other ingredients of the print paste left on the fabric surface after fixation. If not removed, these materials could interfere with subsequent (6).

The most important distinguishing characteristic of reactive dyes is that they form covalent bonds with the substrate that is to be colored during the application process. Thus, the dye molecule contains specific functional groups that can undergo addition or substitution reactions with the OH, SH, and NH_2 groups present in textile fibers (8). The formation of a covalent bond between dye and fibre makes it possible to use dyes which, unlike the vat and direct dyes, are of small molecular size and good solubility. These dyes can be brighter, faster-diffusing and, in the hydrolysed form, easily removed in the washing-off process (1). The full gamut of colours in the reactive class of dyes, which is one of its significant advantages, is obtained by employing a wide range of chromophores. The introduction of reactive dyes for cellulosic fibres has given the printer the possibility of using only one type of dye and simple application conditions, in place of the complex permutations necessary at one time (1,9,10). Reactive dyes are extensively used in many textile industries. However, nearly 50% of reactive dyes may be lost in the effluent after the dyeing of cellulose fibers, and are highly recalcitrant to conventional wastewater treatment processes (11). When selecting reactive dyes for printing, the factors of importance for dyeing must be considered, in addition, attention must be paid to print paste stability and staining of the ground during washing-off.

In reactive printing it is most important that the fixation and hydrolysis proceed to completion, so that no dye in reactive form remains to stain the white ground. The choice of dyes to be used must therefore be determined by the fixation equipment available. The actual level of fixation is important, not only for economic reasons as in dyeing but also because unfixed hydrolyzed dye must be removed very thoroughly. A routine washing-off procedure may be inadequate if the percentage of unfixed dye is higher than normal. After cold washing, high temperature and close to boiling point washing processes are used to remove hydrolyzed dye from the fibers. For any reactive dye type there will be a optimum combination of time and temperature to complete the removal by diffusion from the fiber. Longer times will be required if inadequate flow of washing liquor slows down the unfixed dye. Surface-active agents do not, in general, improve the washing effect. If hard water is used, thickener removal will be more difficult and addition of sequestering agents will be required. Designing a new ultrasonic washing-off process that improves removing hydrolyzed dye from the fibers and combines cold and high temperature washing steps will ensure total energy and chemical savings developing printing quality and fastness (1).

The two phenomena attributed to ultrasound are the rapid movement of liquids caused by variation of sonic pressure which subjects the solvent to compression and rarefaction and micro streaming. Simultaneous formation and collapsing of tiny air bubbles result in a large increase in pressure and temperature at microscopic level. Heat induced by the ultrasonic process is adequate for washing process and thus eliminates the need for external heating in many cases. Advantages of ultrasonics in textile wet processing include energy saving by reduced processing temperature, time, and lower consumptions of auxiliary chemicals and further processing enhancement by overall cost control (19). In washing operations, the objective is to remove natural material or impurities (soil) from the surface of the fibre. Laboratory tests have shown that the time of washing of wool can be reduced from 3 h to 15–30 min for an equivalent whiteness with ultrasonic washing. Washing of 100% cotton and 100% polyester fabrics soiled with oil using ultrasound was also studied. Polyester fabrics washed easier and whiteness was improved for the cotton fabrics. Ultrasound was also used for speeding up the washing of cotton fabrics after dyeing and printing with reactive dyes. Ultrasonic treatment speeds up the process 2/3 times.

The main mechanism of cleaning action is by energy released from the creation and collapse of microscopic cavitation bubbles, which break up and lift off dirt and contaminants from the surface to be cleaned. The higher the frequency, the smaller the nodes between the cavitation points which allows for more precise cleaning (20). Simultaneous formation and deflation of micro bubbles results in an increase in pressure and temperature in the dye bath at microscopic level (23). This induced heat is generally adequate for wet processing and thus decreases the need for external heating. Table 1 shows frequency intervals for different textile wet processing.

The effect of ultrasound in dye bath can be explained as dispersion effect, degassing and accelerating the rate of diffusion of the dye or finishing chemicals inside the fiber accelerating the interaction between dye bath and fiber (21).

Table1. Ultrasonic Frequency and Power Outputs for Different Wet Processes

Ultrasound Frequency (kHz)	Power Output (W)	Application
30- 47	230	Scouring/washing of gray fabric
20-24	600	Desizing
20	---	Natural dyes on cotton and blends.
26	120	Disperse dyeing
20	180-600	Disperse, direct, acid, basic dyeing

There have been many studies about effect of ultrasound on wet processing of textile finishing and they have generally researched effect of different frequency intervals and power outputs on dyeability or pretreatment of fabrics (24-38). Ultrasound allows for process acceleration and attainment of the same or better results than existing techniques under less extreme conditions, i.e., lower temperature and lower chemical concentrations. Textile wet processes assisted by ultrasound are of high interest for the textile industry for this reason. A review of earlier studies using ultrasound in textile wet processes was compiled by Thakore et al. (39). There are also some reports on the application of ultrasound relating to the preparation of auxiliary baths for processes such as the preparation of sizes, emulsions, dye dispersions and thickeners for print paste. In spite of encouraging results from laboratory-scale studies, the ultrasound-assisted wet textile processes have not been implemented on an industrial scale as yet. In this study, real after-treatment conditions of reactive printing line in Zorluteks A.Ş. Kırklareli-Turkey, were investigated and ultrasonic washing process was tried to be adapted on the line.

2. MATERIAL AND METHOD

The main purpose of our project is designing of an ultrasonic washing process as an after-treatment for developing reactive printing quality and fastness of the fabrics. Thus improving energy, chemical and time efficiency within the context of reactive printing is expected.

In Zorluteks printing line, fabrics which have three different colors and weave were printed in rotary screen printing machine. Half of them were washed in traditional washing machine and the other half were taken to experiment with ultrasound washing machine in our laboratory. The washed fabrics were washed again and UV absorbance values of the bath were measured by UV-Visable spectrometer to see their washing off quality after printing. Next, fastness tests were done and certain quality values of the fabrics were observed. The whole test results were evaluated and determined the problematic fabrics. Based on the experiments, it was given a start to new tries for new design. According to our new design study and experimental design, studies were performed with new receipts which had parameters such as tempereture, time and amount of chemical. UV absorbance values of samples were measured in UV-Visable Spectrofotometer. According to the optimum receipt and UV values combination potential washing receipts were chosen. The fastness tests were carried out of potential washing receipts. The best receipts were determined by using benefit value analysis.

2.1 Materials

Experimental study is based on three parameters: wowen type, color and printing machine. First of all, woven types are plain (1/1), satin and panama which are made from the same raw material, cotton, and they also processed the same pretreatment procedures before printing. These samples are printed to different colors: red, blue and yellow for each woven type that gives us 9 different samples.

Printing receipts of the experimental fabrics are shown in tables 2, 3 and 4.

Table 2. Blue printing paste receipt

Printing recipe for blue		
Used Chemicals	Amount(g)	Role
RMA	100	Reactive dye
Urea	120	Desiccant
Sodium bi carbonate	40	pH adjusting
SetaPrint NDG	12.5	Reduction Inhibitor
Setalgin HV	20	Thickener (natural based)
Pigmapol DTA	13	Thickener (sentetic based)
Water	794.5	
Total	1100	

Table 3. Red printing paste receipt

Printing recipe for red		
Used Chemicals	Amount(g)	Role
RPA	100	Reactive dye
Urea	120	Desiccant
Sodium bi carbonate	40	pH adjusting
SetaPrint NDG	12.5	Reduction Inhibitor
Setalgin HV	20	Thickener (natural based)
Pigmapol DTA	13	Thickener (sentetic based)
Water	794.5	
Total	1100	

Table 4. Yellow printing paste receipt

Printing recipe for yellow		
Used Chemicals	Amount(g)	Role
RGS	100	Reactive dye
Urea	120	Desiccant
Sodium bi carbonate	40	pH adjusting
SetaPrint NDG	12.5	Reduction Inhibitor
Setalgin HV	20	Thickener (natural based)
Pigmapol DTA	13	Thickener (sentetic based)
Water	794.5	
Total	1100	

2.2. Equipments

Agilent 8453E UV-Visable Spectrometer**:** UV Spectrometer is used to measure the absorbance value of fabrics'washing water. According to the fabric color, various wavelengths between 400-700 nm are entered to the spectrometer.

In order to determine the color fastness of the fabrics, washing (for 40°C and 60°C), water and rubbing fastness tests were carried out according to TS EN ISO 105-C06 standards by using Linitest Laboratary Type Machine, TS EN ISO 105-E01 standards by using Etuv and TS EN ISO 105 X12 standards by using Crockmeter respectively.

The washing processes are carried out in Intersonic washing machine which has 26kHz frequency and 120 Watt power. Washing ratio for Red Panama Fabric is 1:105 in the Zorlu Textile whereas it is 1:106 in our ultrasonic bath.

2.3. Design Methodology

The main purpose of our project is designing of an ultrasonic washing process as an after-treatment for developing reactive printing quality and fastness of the fabrics. Thus improving energy, chemical and time efficiency within the context of reactive printing is expected. First of all standard washing process of Zorluteks (see in Fig.1) was investigated after printing processes.

There are nine baths that are washing the fabric with water treatment but only the sixth one contains cleaining agent, Hidroksi-Clean CONS HC-25. There are front and take-off rollers between baths which remove residiuary dye from fabric surface.

First 2 Baths: Washing only in 40°C water

3rd Bath: Washing only in 60 ^{0}C water

4th and 5th Baths: Washing only in 95°C water

6thBath: Washing in 4 g/l, 95°C solution and waiting for 2 minutes.

7th Bath: Rinsing of fabric in 95°C water

8th Bath: Rinsing of fabric in 70 °C water

9th Bath: Neutralization in pH 4,5 acetic asit, 80 ^{0}C solution.

For 100 kg fabric, 0.56 m^3 water is fed to all baths but pre-washing (0.8 m^3) which means 0.56 m^3 waste water for whole baths.

In addition, for unit fabric (for our samples), the cleaning process is taking 10 minutes.

It is seen that how much water, heat energy and chemical is used in the standard washing procedure in Zorluteks. So, in order to reduce all consumption for washing process, ultrasound system could become a solution.

It is assumed that the result of washing will be more effective when it is entegrated to the washing tanks considering ultrasound's cavitation ability. So it could be possible to decrease the number of washing bath which means reducing water consumption. In addition, it is possible to lower the temperature and use of cleaning agent.

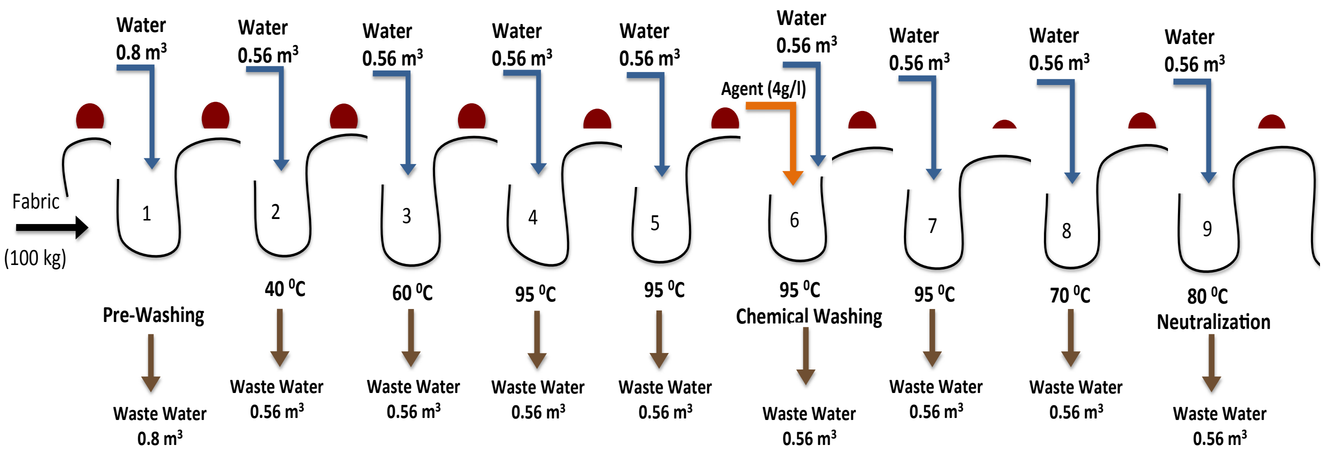


Figure 1. Washing process of Zorluteks

First of all, the nine different fabrics washed in Zorluteks are washed in ultrasound machine again and their washing baths are measured using UV-VIS spectrafotometer in order to see their washing efficiency. Within the scope of the UV-Vis measurments and fastness tests evaluations of the fabrics, the samples which have quality problem were chosen to carry out for ultrasonic washing experiments. Ultrasonic washings are performed by changing the temperature, time and amount of chemical parameters. Our target is create optimum washing condition and quality. So, minimum usage of cleaning agent, minimum temperature and maximum UV values are tried to be obtained by regression analysis.

As a consequence, the model which has most adequate parameters and fastness values will be the actual desing process. In order to determine the actual Model, utility value analysis is applied.

2.4. Experimental Study

The fabrics washed in Zorluteks are washed in ultrasound machine again and their washing bath samples were measured by using UV-Vis spectrofotometer. UV absorbance values of the fabrics washed by Zorlu Textile are seen in Table 5.

According to the UV values, it is clear that there is a certain color absorbation for red panama fabric. This value shows that it has poor fastness values. In order to determine the color fastness of red panama washed in Zorluteks, washing (for 40°C and 60°C), water and rubbing fastness tests were carried out and evaluated relevant standards. The test results are shown in Table 6, 7, 8 and 9.

It is clearly seen from the table 6, 7, 8 and 9 red panama fabric has washing efficiency problem with poor water fastness and wet rubbing values whereas the other fabrics have no fastness problem. Thus, unwashed red panama was chosen as a sample for ultrasonic washig experiments. The washings are performed by changing the temperature, time and amount of chemical parameters. The target is to create optimum washing condition and quality. So, minimum usage of cleaning agent, minimum temperature and maximum UV values are tried to be obtained after 24 different washings in the ultrasonic washing machine by regression analysis. Figure 2 shows the time and UV absorbation relation analysis of the red panama samples.

Table 5. UV absorbance values of the fabrics washed by Zorluteks

Fabric Number	Fabrics Washed in Zorlu Textile	UV abs ($x10^{-3}$)
1	Yellow Plain	20.689
2	Yellow Satin	26.249
3	Yellow Panama	26.889
4	Blue Plain	13.729
5	Blue Satin	13.817
6	Blue Panama	20.649
7	Red Plain	38.749
8	Red Satin	44.823
9	Red Panama	109.59

* 25 °C to 40 °C / 30 min

Table 6. Washing fastness (for 40°C) of fabrics washed in Zorluteks

40 °C	Yellow Plain		Yellow Satin		Yellow Panama		Blue Plain		Blue Satin		Blue Panama		Red Plain		Red Satin		Red Panama	
Washing Fastness	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change
Asetat	4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5	
Cotton	4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5	
Nylon	4/5	4-5	4/5	4-5	4/5	4-5	4/5	4-5	4/5	4-5	4/5	4-5	4/5	4-5	4/5	4-5	4/5	4-5
PES	4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5	
Acrylic	4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5	
Wool	4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5	

Table 7. Washing fastness (for 60 ^{0}C) of fabrics washed in Zorluteks

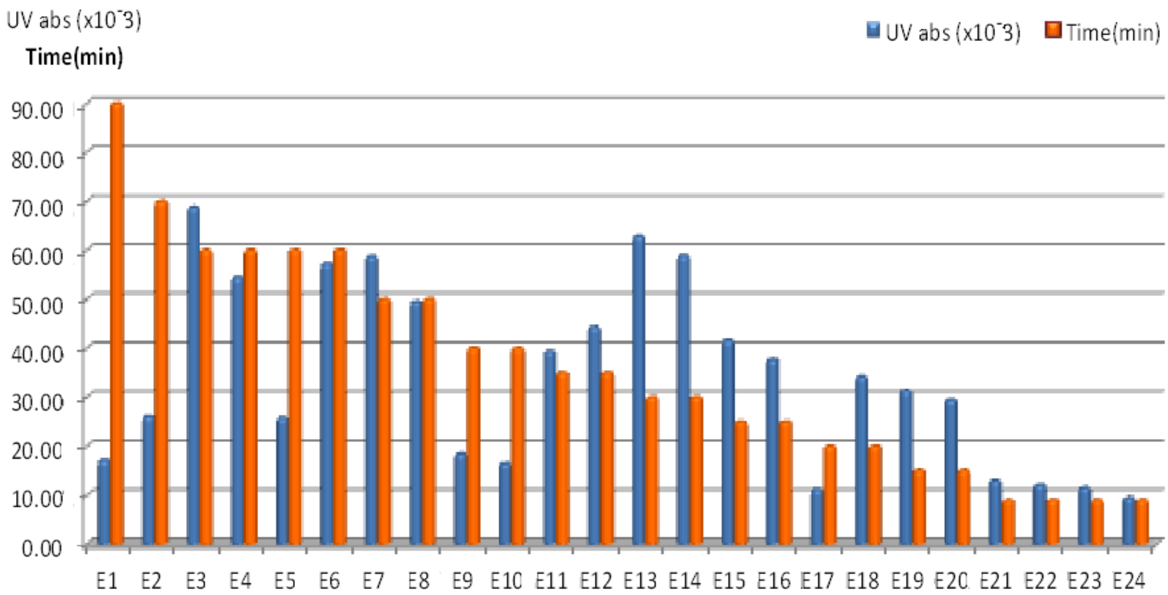
60 °C	Yellow Plain		Yellow Satin		Yellow Panama		Blue Plain		Blue Satin		Blue Panama		Red Plain		Red Satin		Red Panama	
Washing Fastness	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change
Asetat	4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5	
Cotton	4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5	
Nylon	4/5	4-5	4/5	4-5	4/5	4-5	4/5	4-5	4/5	4-5	4/5	4-5	4/5	4-5	4/5	4-5	4/5	4-5
PES	4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5	
Acrylic	4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5	
Wool	4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5	

Table 8. Water fastness of fabrics washed in Zorluteks

Water Fastness	Yellow Plain		Yellow Satin		Yellow Panama		Blue Plain		Blue Satin		Blue Panama		Red Plain		Red Satin		Red Panama	
	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change	Staining	Color Change
Asetat	4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5		3/4	
Cotton	4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5		3	
Nylon	4/5	4-5	4/5	4-5	4/5	4-5	4/5	4-5	4/5	4-5	4/5	4-5	4	4-5	4	4-5	3/4	4-5
PES	4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5		3/4	
Acrylic	4/5		4/5		4/5		4/5		4/5		4/5		4/5		4/5		3/4	
Wool	3/4		3/4		3/4		3/4		3/4		3/4		3		3		3	

Table 9. Rubbing fastness of fabrics washed in Zorluteks

Rubbing	Yellow Plain		Yellow Satin		Yellow Panama		Blue Plain		Blue Satin		Blue Panama		Red Plain		Red Satin	
Fastness	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Cotton	3/4	4/5	4	4/5	3/4	4/5	4	4/5	4	4/5	4	4/5	3/4	4/5	3/4	4/5



E: Number of red panama samples

Figure 2. Time and UV absorbation relation analyses of the red panama samples

As seen from the figure 2, the last 4 receipts are the most convenient ones as their adequate UV absorbtion values and washing time. Color fastness tests of those E21, E22, E23 and E24 showed beter fastness (for all color fastness parameters = 4/5) value than the red fabrics washed according to standard washing process.

3. RESULTS AND DISCUSSION

After experimental study, new potential design alternatives are E21, E22, E23 and E24 which becomes our Model 1, Model 2, Model 3 and Model 4. The difference between the models are temperature, amount of chemical and UV absorbsion values that help to choose one of them. In order to analyse the optimum values which were mentioned before, UV spectrometer and fastness tests were used. Then the results were analyzed on the graphs that were plotted to see relation between parameters. So, the graphical analysis method led us to determine the actual receipt.

Based on time and quality restriction, four main models were determined before. Now, by using two other secondary parameters temperature and use of chemical, second graph analysis shown in the figure 3.

As the target is to reduce temperature and chemical, providing adequate quality, Model 1 (E21) seems to be the best alternative.

The approach which was followed to improve the design is regression analysis. By using regression analysis, the recipes were adjusted and the temperature, the amount of chemical and time were closed up to the wanted values step by step. Because of the time and chemical restriction, time was firstly decreased seriously but to compansate this, temperature and amount of chemical was increased. However, it can be seen that the amount of chemical is same after a while because of chemical restriction.

The results of every recipes were compared and revised to the result which we desire to have; optimum time, temperature and chemical usage.

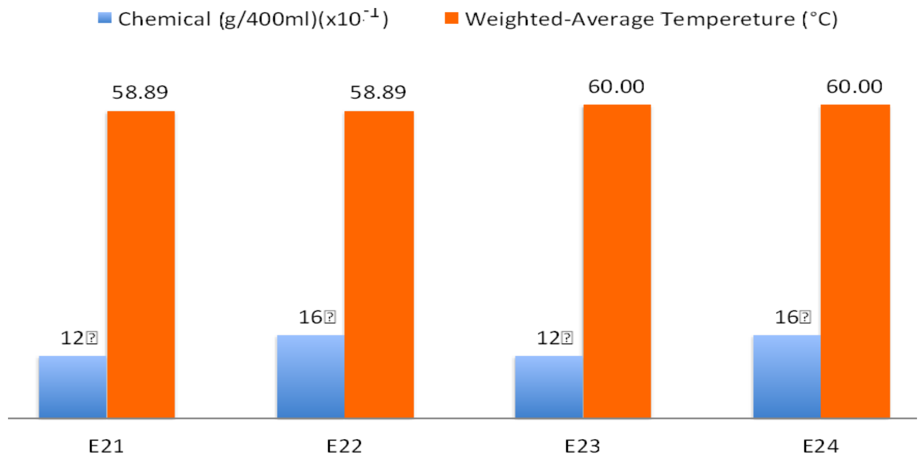
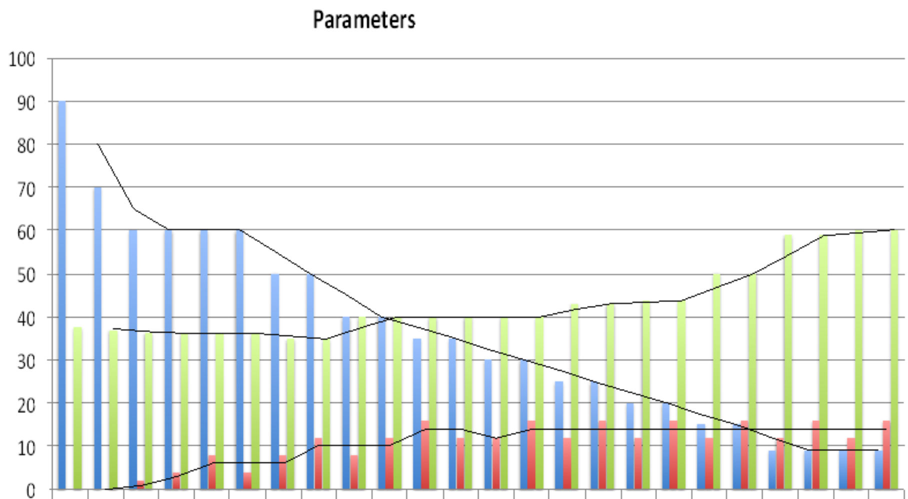


Figure 3: Chemical and weighted- average temperature relation analyses



	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24
Time (min)	90	70	60	60	60	60	50	50	40	40	35	35	30	30	25	25	20	20	15	15	9	9	9	9
Chemical (g/400ml)(x10-1)	0	0	2	4	8	4	8	12	8	12	16	12	12	16	12	16	12	16	12	16	12	16	12	16
Temperature(°C)	37.5	36.8	36.3	36.3	36.3	36.3	34.8	34.8	40.0	40.0	40.0	40.0	40.0	40.0	43.0	43.0	43.8	43.8	50.0	50.0	58.9	58.9	60.0	60.0

Figure 4. Trendline of changing parameters

According to the analyses, the actual receipt is obtained and the Model1 is formed as shown in the Figure 5.

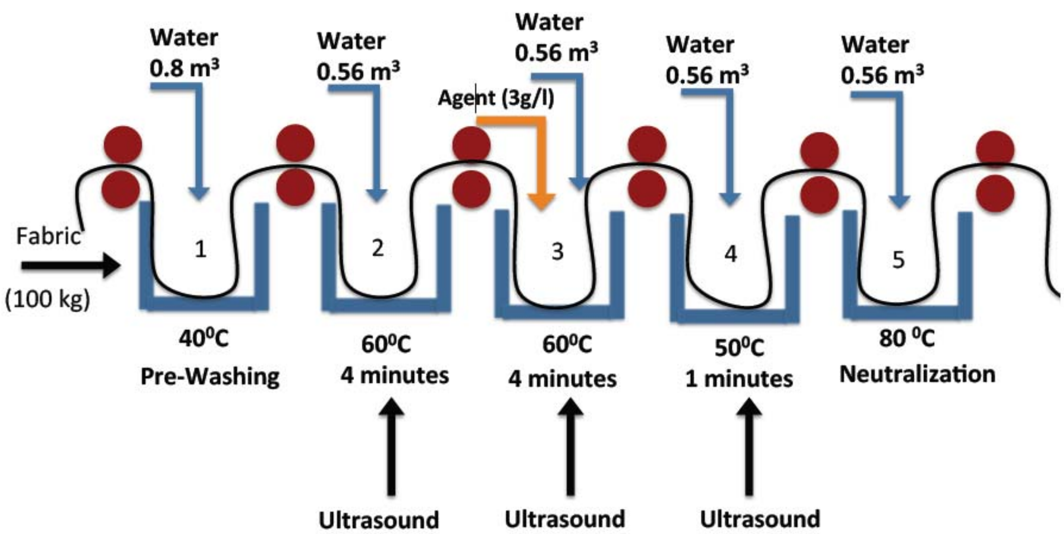


Figure 5. Application of Model 1 to the standard washing line

In the model I, the total process will take 10 minutes and the 3 washing parts that we worked on it will take nine minutes by the entegration of ultrasound system to those three washing baths. It is not difficult to entegrate the ultrasound system to the washing tanks.

4. CONCLUSION

In order to make the certain comparison of two red panama fabrics that are washed with both standard receipt and Model 1, the water fastness test and UV absorbance measurements are performed. UV absorbance values are shown in table 10.

As it shown in the figure 6, the water fastness value of number 9 (staining) is very poor. It is easy to see the remarkable difference between two washings. This condition shows the ultrasound system cleaning ability properly.

According to experimental results four washing off models were obtained as shown in figure 7. Model 1 is chosen as an actual receipt because it gives highest efficiency to the system reducing the number of washing tanks from 9 to 5 . Its average washing temperature and the chemical usage are lower than others. Despite all, the fastness values are in desired level. The temperature is reduced from 95 ^{0}C to 60 ^{0}C. Due to 25% decrease (from 4 g/L to 3 g/L.) in chemical consumption using ultrasound system chemical costs also decrease by 25%. Moreover, Because the number of washing bath is reduced, the redundant washing tanks and rollers are not required anymore.

Table 10. Comparing the UV values of problematic fabric to E21 washed by chosen receipt

Number	Fabric	Final UV (abs) Values
9	Red Panama	0.1096
E21	Red Panama	0.0071

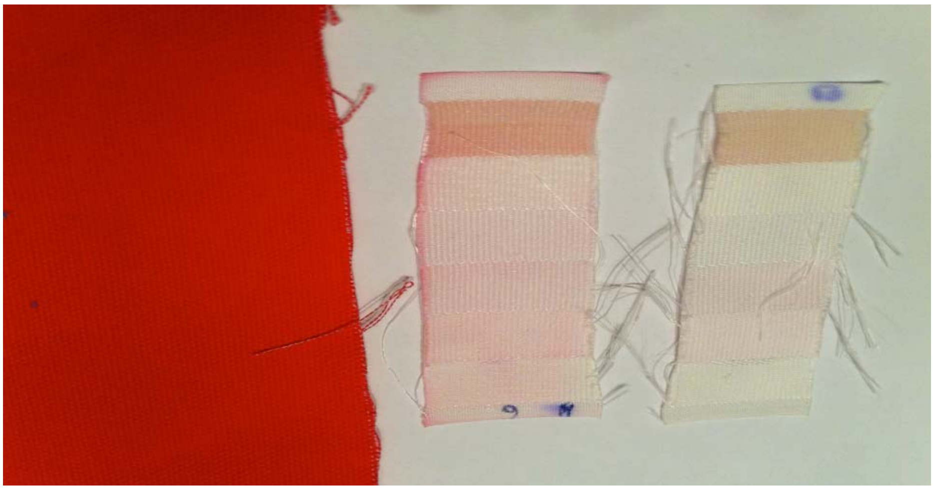
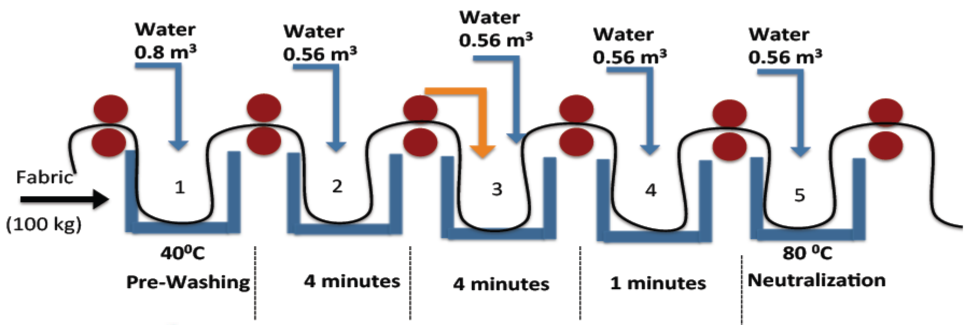


Figure 6. Comparison of the water fastness values of problematic fabric to E21 washed by chosen receipt



Model 1	Chemical:0 Temperature:60°C	Chemical:1,2g/400 ml Temperature:60°C	Chemical:0 Temperature:50°C UV(x1000):12,93
Model 2	Chemical:0 Temperature:60°C	Chemical:1,6g/400 ml Temperature:60C	Chemical:0 Temperature:50°C UV(x1000):12,16
Model 3	Chemical:0 Temperature:60°C	Chemical:1,2g/400 ml Temperature:60°C	Chemical:0 Temperature:60°C UV(x1000):11,53
Model 4	Chemical:0 Temperature:60°C	Chemical:1,6g/400 ml Temperature:60°C	Chemical:0 Temperature:60°C UV(x1000):9,45

Figure 7. New design alternatives

New ultrasound entegrated system obtains rather environmentally friendly production. Because, reducing of water consumption decreases the amount of waste water. Furthermore, less chemical agents reduce the contamination of waste water which will be discharged to the soil. Finally, the thermal pollution will be minimized owing to decreasing washing temperature.

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