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The Effect of Ultrasonic on the Denim Fabric Worn out Process

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Abstract: In the presented research the effects of ultrasonic US on worn out process is under consideration. Samples of two different vats dyed denim fabrics chosen and were worn out with the aid of sodium hydrosulphite and neutral cellulase enzyme individually and together and the effects of ultrasound were investigated in parallel testes. Pictures were taken from samples by microscope and scanning methods and the amounts of brightness, color difference, degree of whiteness and color absorption of treated samples in US and ordinary environments were determined and compared. The back staining effects were also evaluated by the aid of degree of whiteness for samples. All the measured parameters were varied and increased between 50 to 98% for US environment and the back staining effects were declined in the presence of US significantly. It was concluded that the general properties of US wave especially in wet processes makes it applicable in worn out process for improving the efficiency and producing a different view, color change and fluffy look.

Key words: Worn out, denim fabric, ultrasonic, neutral cellulase, sodium hydrosulphite

INTRODUCTION

Over the last few decades various garment washing techniques have been used on different material types to create a large variety of attractive fashions in garments. Since denim constitutes the largest portion of the garments that are washed, the term wash has come to mean the finishing of denim garments (Chong, 1994). Denim washing is generally divided into the following categories:

- Stone Washing: Pumice stones are added to the garments during washing as abrading agent. Color fading is more apparent but less uniform. The degree of color fading depends on the washing time, stone ration, size of stones, liquor ratio and garment load.
- Enzyme Washing (Bio-stoning): This is bio-catalytic method wherein an ultra-soft handle effect can be produced on denim. The hydrolytic effect of enzymes causes the loss of surface fiber, which improves surface smoothness and softness of the fabric.
- Bleach Washing: This process is usually done without stones by using an oxidative bleaching agent like hypochlorite or bleach with reducing agent like sodium hydrosulphite. These chemical agents are normally used as these are cheap, convenient and quick.

Today, use of enzymes and bleaching agent to stonewash has become increasingly popular because use of stones alone has several disadvantages. For example, stones used in the process causes wear and tear on the machinery, they cause environmental waste problems due to the grit produced and result in high labor costs associated with the manual removal of the stones from pockets of garments. Consequently, reduction or elimination of stones in the wash may be desirable.

In view of that fact, ultrasound appears to be a very promising alternative technique to provide a far more efficient stirring/mixing mechanism for the immediate, border layer of liquid at the fiber's surface. Generally, sonication of liquid causes two primary effects, namely, cavitation and heating. When microscopic cavitation bubbles collapse at the surface of the solid substrate, they generate powerful shock waves that cause effective stirring/mixing of the adjusted layer of liquid (Blanchard *et al*., 2004). The common features of using ultrasound is: Cutting and sewing (Dermott, 2001), textile wet processing (Michielsen and Beckham, 2004), elimination of polyester fiber oligomers (Cunko *et al*., 2001), preparation of non-woven fabric reinforced polyacrylonitrile (Hirata *et al*., 1992), low temperature dyeing of polyester (Bhatlacharya, 2000), dyeing polyamide/lycra blend (Merdan *et al*., 2004), enzyme treatment of cotton fabric (Yachmenev *et al*.,1999) and etc.

According to the literature survey and the history of ultrasonic, it has been very useful in a wide variety of applications, including textile treatments such as washing, dyeing and etc. The objective of the presented paper is to investigate the effectiveness of ultrasonic environment in making a different worn out appearance on denim fabrics,

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which can be used as a complementary measure for reducing chemicals in the treatment and for making a various look on the fabric.

EXPERIMENTAL

All the tests were done in Islamic Azad University Research and Science Campus and Iran Color Research Center in 2006.

Samples of two kinds of blue and black denim fabrics (Table 1) with two neutral cellulase enzymes and sodium hydrosulphite (Table 2) were treated as depicted in Table 3. Time, temp, L:R were the same for all the samples 60 min, 50°C, 1:100 orderly and twenty four series of samples were treated.

In 1 step method 4.5 g L^{-1} of cellulase enzyme with 2.5 and 5 g L^{-1} hydrosulphite lonely or simultaneously together were used and in 2 step method, first the same amount of enzyme as before applied then 2.5 or 5 g L^{-1} of hydrosulphite were added to the samples (Table 3).

To observe and take pictures of produced changes on the appearance of samples a Projectina microscope (No. 4014 Swiss made) and a Fujitsu scanner (No. Fi-4010, resolution = 100) used.

Color coordinates L*, a* and b* of treated samples determined by a reflective spectrophotometer (COLOUR EYE 7000A of Macbeth brand with view angle of 60°C and the light source D_{65} in dye standard of CIELAB) and by using 1 and 2 relations the ΔE*and W were obtained.

The Abs and λ_{max} of samples determined by an absorption spectrophotometer (CECIL2021 Single Beam in the range of 200 to 700 nm).

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

$$W\ (Stensby) = L - 3b + 3a \quad (2)$$

RESULTS AND DISCUSSION

The Microscope and scanned pictures of samples are depicted in Table 4, it can be seen that the microscopic and scanned pictures are in accordance with each other. The scanner was used for eliminating the texture of fabric for better comparison of the degree of whiteness and observing the produced fluffy state of the samples. On the other hand the contrast between weft and wrap yarns is more discriminative in microscopic pictures.

The treated samples in us environment show notable difference in comparison with their partner in the non-us environment and the whiteness of chemically treated samples is more than biologically treated ones.

Table 1: Denim fabrics specifications

Fabric	Weave kind	Wrap count (Tex)	Weft count (Tex)	Wrap density (cm)	Weft density (cm)	Weight (g/cm^2)
Blue jean	Twill	110.43	67.7	23	20	426
Black jean	Twill	82.40	72.2	16	16	402

Table 2: The specifications of applied materials

Materials		Company	Appearance	Class	pH limits	Temp limits	Material amount
Enzymes	GI	Dawchem	Powder	Neutral	5-9	40-60°C	0.5-2% owf
	TJ-2000	Makrosol	Powder	Neutral	All range	40-60°C	20-40 g kg^{-1}
Hydrosulphit sodium		Merk					

Table 3: Various procedures of worn out treatments for different series of samples

Sample No.	Enzyme	Hydro (g L^{-1})	Step	Environment
1	-	2.5	1	US
2	-	2.5	1	Non-US
3	-	5	1	US
4	-	5	1	Non-US
5	GI	-	1	US
6	GI	-	1	Non-US
7	TJ	-	1	US
8	TJ	-	1	Non-US
9	GI	2.5	1	US
10	GI	2.5	1	Non-US
11	GI	5	1	US
12	GI	5	1	Non-US
13	GI	2.5	2	US
14	GI	2.5	2	Non-US
15	GI	5	2	US
16	GI	5	2	Non-US
17	TJ	2.5	1	US
18	TJ	2.5	1	Non-US
19	TJ	5	1	US
20	TJ	5	1	Non-US
21	TJ	2.5	2	US
22	TJ	2.5	2	Non-US
23	TJ	5	2	US
24	TJ	5	2	Non-US

Table 4: Microscopic and scanned pictures of treated samples

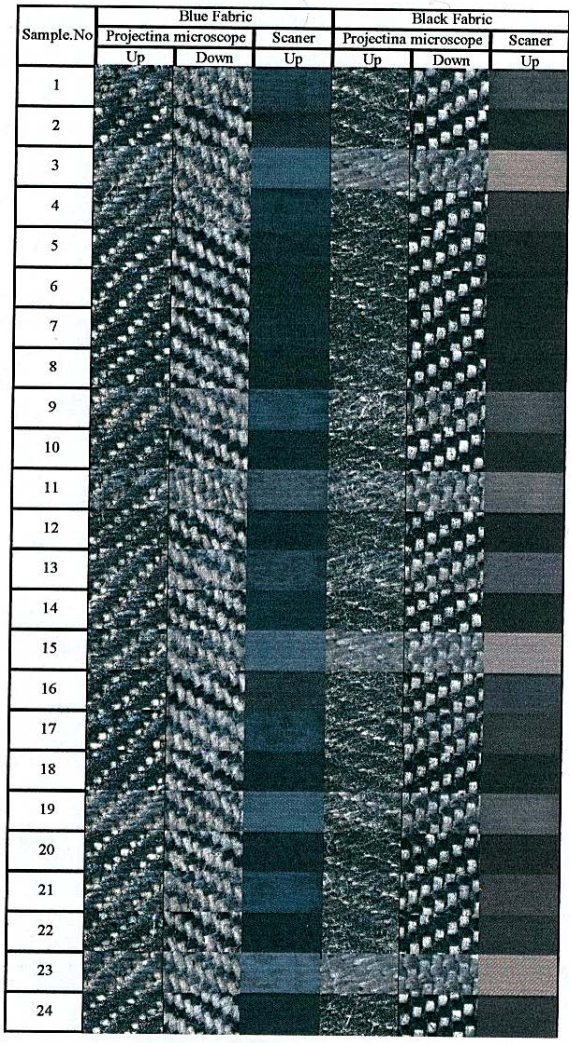

Table 5: Categorized the most whiteness changes of treated samples by viewers in three different groups; Minimum, moderate and maximum changes

Minimum changes		Moderate changes		Maximum changes	
Blue	Black	Blue	Black	Blue	Black
1	1	11	11	3	3
9	9	19	19	13	13
13	13			23	23
17	17				
21	21				

According to the viewers the amount of obtained whiteness for samples in Table 4 were divided into 3 main groups; Minimum, Moderate and Maximum changes with the aid of scanned samples (Table 5).

The results of the Table 5 can be summarized as below:

- Maximum changes belong to hydro 5 g L^{-1} and hydro 5 g L^{-1} with enzyme in 2 step method.
- Moderate changes are for hydro 5 g L^{-1} with enzyme in 1 step method.
- Minimum changes occurred in hydro 2.5 g L^{-1} and hydro 2.5 g L^{-1} with enzyme in 1, 2 step methods.

CIELAB color coordinates: L*‘ a* and b* values for blue and black denim fabrics (up and down side) before and after treatment and the ΔE*‘ W values for each sample are shown in Table 6 and 7.

The resultant values of brightness, color difference and white degree for acted samples with sodium hydrosulphite individually and with enzyme on the up side of denim fabrics (Table 6) revealed that all the inspected factors as result of ultrasonic environment revenue were more than non-ultrasonic environment. All of these factors on the down side of worn out samples were like the up side. The important factor on the down side of fabric which is backstainnig (evaluated by the degree of whiteness) increased in all the samples treated with hydro individually and with enzyme indicated that this undesirable effect reduced on ultrasonic

Table 6: L*‘ ΔE and W values for blue and black denim samples (up side)

Sample	Blue jean (up side)			Black jean (up side)		
No.	L*	ΔE*	W	L*	ΔE*	W
1	25.161	6.054	57.651	34.169	17.199	38.981
2	24.744	1.071	43.26	19.095	2.359	24.582
3	37.825	14.928	66.066	66.805	50.36	46.921
4	22.598	7.624	34.865	24.733	7.808	30.814
5	24.171	2.239	45.537	18.089	1.077	22.409
6	23.309	1.344	43.001	17.84	0.925	22.181
7	21.535	4.349	43.711	16.405	0.967	21.313
8	21.271	4.07	43.558	16.127	0.751	20.579
9	33.11	9.779	61.979	37.983	21.034	41.352
10	22.907	2.378	39.747	19.437	2.882	24.669
11	38.571	14.053	61.844	47.829	30.817	45.579
12	22.408	3.655	45.607	17.587	0.899	22.348
13	31.403	8.515	63.692	43.241	26.233	43.892
14	24.171	4.643	53.106	18.894	1.942	23.837
15	35.279	10.959	60.074	68.42	51.926	48.431
16	24.101	2.407	46.604	33.152	16.234	37.211
17	29.312	5.951	56.393	29.562	12.593	34.686
18	23.08	2.745	44.419	17.029	0.46	22
19	38.445	14.389	63.909	41.879	24.85	42.8
20	23.347	2.918	46.639	17.289	0.726	22.269
21	32.605	10.874	65.353	31592	14.593	36.818
22	21.791	5.224	50.417	24.184	7.521	30.742
23	30.421	8.487	65.2	65.272	48.796	45.799
24	24.265	1.698	44.848	23.615	6.769	29.57

environment. The changes on the samples that acted with enzyme individually weren't as reacted with chemical agents (Table 7).

The wastewater color absorption (λ_{max},Abs) obtained values of treated samples with hydrosulphite individually and/or with two kinds of enzymes on both fabrics shows that color absorption was much higher for ultrasonic environment, in other words color removal was higher with applying US. The changes on the samples that acted with enzyme lonely weren't like those whom reacted with chemical material (Table 8).

Table 7: W values of treated blue and black denim samples (Down side)

Sample No.	W (Blue Jean)	W (Black Jean)
1	66.541	55.695
2	55.275	46.243
3	73.601	58.274
4	70.115	48.65
5	56.212	40.079
6	54.796	39.275
7	55.675	40.219
8	51.538	40.212
9	68.454	58.377
10	58.12	48.208
11	72.703	60.883
13	69.85	57.673
14	66.163	39.518
15	68.412	59.202
16	60.104	53.574
17	67.443	57.483
18	63.571	40.521
19	68.371	60.46
20	58.468	40.635
21	71.752	54.288
22	60.85	47.492
23	74.5	59.343
24	54.155	47.02

Table 8: λ_{max}(nm) and Abs (A) changes on wastewater of treated blue and black fabric samples

Sample	Blue Jean				Black Jean			
No.	λ_{max}	Abs	λ_{max}	Abs	λ_{max}	Abs	λ_{max}	Abs
1	288	0.82	697	0.419	260	1.832	590	0.172
2	288	0.425	697	0.01	260	0.64	580	0.042
3	292	0.672	672	0.315	260	0.44	580	0.365
4	292	0.42	672	0.1	260	0.09	546	0.07
5	260	0.69	580	0.06	260	0.46	580	0.042
6	260	1.025	580	0.043	260	0.42	580	0.034
7	355	0.455	580	0.187	275	0.616	581	0.112
8	355	0.03	580	0.032	275	0.472	581	0.088
9	286	1.598	674	0.682	259	1.916	586	0.214
10	286	0.54	674	0.034	259	0.78	586	0.03
11	286	0.62	678	0.131	262	2.892	590	0.222
12	286	0.57	678	0.025	262	0.73	580	0.028
13	284	1.26	672	0.342	328	0.55	581	0.212
14	284	0.64	672	0.064	328	0.12	580	0.026
15	283	1.025	673	0.167	428	0.27	582	0.311
16	283	0.84	673	0.03	427	0.095	580	0.102
17	355	0.851	686	0.555	261	1.726	587	0.216
18	355	0.2	686	0.01	261	0.41	580	0.061
19	355	0.8	689	0.631	271	2.1	586	0.247
20	355	0.14	689	0.025	271	0.485	580	0.016
21	355	1.273	684	0.773	261	1.85	590	0.239
22	355	0.27	679	0.028	261	1.49	580	0.053
23	355	0.687	688	0.028	430	0.24	588	0.339
24	355	0.143	688	0.01	430	0.04	580	0.06

CONCLUSIONS

- Ultrasounds increase the intensity of enzymatic and chemical reactions hence saving the reactants and time.
- Ultrasounds cause abrasion and more solution displacement on fabric surface.
- Ultrasound decreases the back staining on the back of denim during worn out processes as a result of diminishing of carrier property of enzymatic processes.
- According to previous studies ultrasonic has no diverse effect on the enzyme proficiency e.g. it does not changing the second structure of enzyme.
- Using enzymes in bio-stoning can eliminates or reducing the usage of pumice stone in worn out treatment consequently decreasing process costs and less damages to the equipments.
- Applying sodium hydrosulphite together with ultrasonic environment increases the efficiency of the worn out process significantly.
- Treating garments in ultrasonic environment produce non-homogenous effects on fabric which can be advantages in this kind of finishing.
- Using sodium hydrosulphite together with enzyme in ultrasonic environment produces special pretty effects because the enzyme prevents the harshness of chemical reaction which could replace with common worn out methods.

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