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DYEING OF KNITTED MICRO-VISCOSE IN THE PRESENCE OF ULTRASOUND WITH DIFFERENT FREQUENCIES

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Abstract: *In dyeing process, the object is to transport or diffuse dyes and chemicals into the fibre. Various novel processes, including ultrasound, are being introduced and studied as more environmentally friendly alternatives. Encouraging results have been reported for the use of ultrasound energy in dyeing processes of micro-viscose. The recent studies revealed major ultrasound applications advances: savings of processing time, energy, chemicals, as well as environmental protection. Influence of various ultrasound frequencies (40, 200 and 400 kHz) on dyeing of micro-viscose knitted fabrics, by a reactive dye has been reported in this work. A method of reflection spectrophotometry has been employed to record reemission curves of the colored compounds. A software packet has been employed to calculate CIELab colored coordinates. Then, a comparison has been made with samples colored by conventional procedure according to CIELab76 and CMC (2:1) criteria. The use ultrasound in textile dyeing processing offers many potential advantages. The results prove better dye exhaustion by ultrasound and consequently the better fixing. The exhaustion for the bifunctional dye (containing two vinylsulphone groups) reaches 71.75 % without ultrasound, and 83.69 % with 400 kHz ultrasound. The 40 kHz, 150 W ultrasound causes a cavitation of higher intensity, compared to 200 and 400 kHz ultrasounds. In this particular case, destruction of cavitation bubbles is very intensive. That is why a large amount of cavitation energy is being transformed into a heat, yielding the additional bath heating. The ultrasounds with higher frequencies (200 and 400 kHz) cannot use such a strong power. The applied powering this case reaches 0.6 W. The cavitation bubbles are now smaller the cavitation disintegration is not so strong, and the energy loss is much smaller, i.e. a smaller amount of energy has been transformed into a heat. An ultrasound of an equal power, but of higher frequency contributes to the somewhat higher exhaustion and fixing. The ultrasound dyeing produces much obscured colours, compared the standard. The differences are evident and not negligible. The comparison of the samples treated ultrasound of different frequencies during dyeing revealed the higher coulours intensities with the increase of ultrasound frequencies of the equal power (200 and 400 kHz). However, the increase is not so expressed.*

Key words: *knitwear, dyeing, micro-viscose, ultrasound, CIELab.*

1. INTRODUCTION

Exhaustion dyeing of textiles proceeds through migration of dye molecules from the bath to the fiber surface, then a slower diffusion process takes place into the fiber. Ultrasound applied to dyeing processes enables dye dispersion breaking up the molecular aggregates and contributes to agitation enhancement of the bath with a consequent thickness reduction of liquid boundary layer surrounding the fibers. Sometimes ultrasound can induce fiber swelling which increases the dye diffusion rate inside the fiber. The fundamental benefit commonly ascribed to ultrasound is a mass transfer improvement, which can be otherwise achieved by higher temperatures, longer times and introduction of auxiliary chemicals [1-3].

The effect of ultrasonic energy on dyeing processes was already widely investigated on cotton, wool, silk, acrylic, nylon, polyester with good effects in all cases. In fact, it was observed that the action of ultrasound (600 W, 20 kHz) enables to increases dye diffusion coefficient of 30 % allowing a dyeing time reduction of 20 % at the same temperature. In the case of polyester dyeing with disperse dyes the ultrasound benefit is still more relevant due to advantages like ultrasonic waves helping in breaking up the dye aggregates, stabilizing the dispersion and accelerating the diffusion rate of the dye inside the fiber [4-10].

The presented papers point to the fact that ultrasound has a great potential for practical application, considering its contributions with enhanced productivity, easier processing control and reduced pollution of waste waters.

Taking into consideration that ultrasonic vibrations create compression and refraction in water, i.e. areas of high and low pressure, as a corollary of refraction there occur bubbles, which swell until, during the stage of compression, they abruptly disintegrate causing shock in the mass. This phenomenon of creation and disintegration of bubbles (known as cavitation) is generally responsible for most of the ultrasonic physical and chemical effects observed in solid-liquid and liquid-liquid systems. Thus, ultrasonic energy has been applied in textile industry, as well, for the most part in soaking processes, and textile washing and cleaning.

2. EXPERIMENTAL PART

2.1. Material

The basic characteristics of the used material have been presented on Table 1.

Table 1: *Basic characteristic of undyed fabric interlock 100 % micro viscose*

Machine - knitted Fabric Interlock	
Tt_{yarn}	20 tex
Tt_{fiber}	1,0 dtex
Mass of a square meter	205 gm^{-2}
Illuminant - Whiteness, Berger	83 %

The Drimarene Black R-3B (Clariant International Ltd., Switzerland) is used dye, and it belong to the group of diazo dyes. The gross formula of this dye is $C_{26}H_{21}N_5S_6O_{19}Na_4$, and its molecular mass 991.82 g/mol. The structural formula of this dye has been presented on Figure 1.

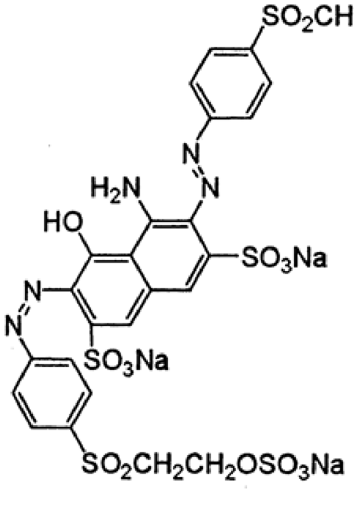

Fig. 1: *Structural formula of used dye*

2.2. Procedure

Dyeing was done in ultrasonic reactor on ultrasound frequencies of 200 and 400 kHz. The applied energy is 0.6 W. The ultrasonic reactor was made some parts like generator, transducer and reaction vessel.

It has been dyed by dye (c = 2.0 % o.w.t) without ultrasound action (conventional method) and under the effect of various frequencies of ultrasound, respectively:

I Conventional method (without ultrasound);
II With ultrasound $\lambda = 40$ kHz;
III With ultrasound $\lambda = 200$ kHz;

IV With ultrasound λ = 400 kHz;

In the experiment viscose microfibre knitwear has been dyed according to the on-line procedure, isothermally at 40°C, for the period of 100 min., at pH 10,4 (pH adjusted with Na_2CO_3) and with 60 g/L NaCl (dye and chemical were added on the very beginning of the process). Dyeing bath ratio is R=1:50. Mechanical mixing was applied during conventional (ultrasonic dyeing performed without mechanical mixing).

Washing of dyed samples was made at the end of treatment: warm rinsing, 15 min on 90°C with 2 g/L Hostapol CV, 10 min neutralization on 40°C (1.5 ml/L CH_3COOH 30 %) and cold rinsing.

2.3. Measurement methods

The color computer that measured the reflectance of the dyed fabrics was a HunterLab ColorQuest XE diffuse/80 with adequate software.

The measurement parameters are:
- Color calculation model: CIELab, CIE (2:1);
- Light source: Daylight D65;
- Standard observer: 10°;
- Number of measurement points of samples was 5;

Samples are, after dyeing but before washing (scouring) divided into two halves. One-half is washed and the other is dried without washing. Dyed samples are measured before and after washing on reflection spectrophotometer and then some parameters were calculated [11].

$$\%E = \frac{A_0 - A_T}{A_0} X100 \tag{1}$$

Where *E*, A_0 and A_r are, respectively, the bath exhaustion percentage, the absorbance of the bath before and after dyeing.

$$\%F = \frac{(K/S)_2}{(K/S)_1} X100 \tag{2}$$

$$\%T = \frac{\%F * \%E}{100} \tag{3}$$

Where *%F* is the percentage fixation of the dye, which exhausted, $(K/S)_1$ and $(K/S)_2$ represent the colour strength of the dyeing before and after stripping of any unfixed colour, *%T* is the overall percentage fixation.

3. RESULTS AND DISCUSION

Rate of exhaustion curves for dye on cellulose fabrics whew obtained by measuring the dye bath concentration at 10 min (Fig. 2). Intervals between 0 and 100 min during the dyeing process. The amount of dye in the residual bath was measured on Philips model PU UV/visible spectrophotometer at wavelength of absorption maximum (λ = 585 nm).

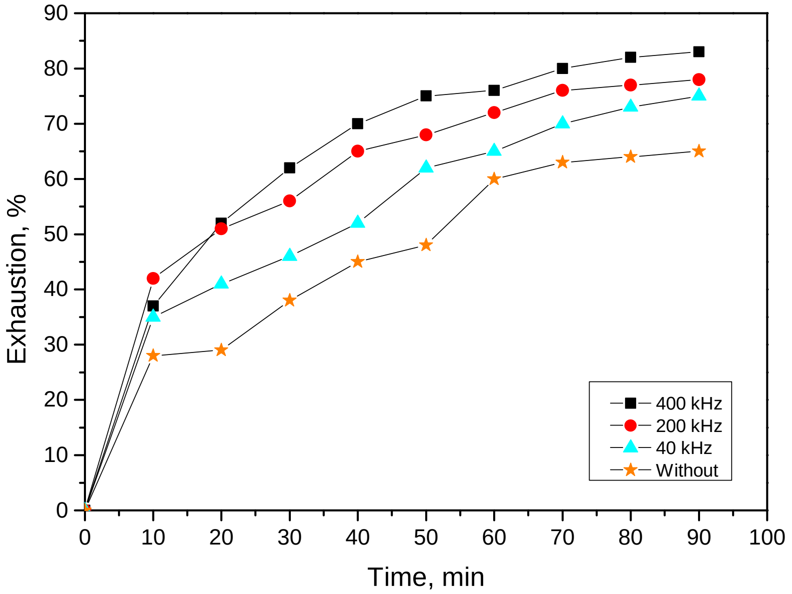

Fig. 2: *Exhaustion diagram for used dye*

Table 2: *Some results of performed measurements during dyeing*

Dyeing method	**%E**	**%F**	**%T**
without US	71.75	95.80	68.74
40 kHz	78.90	99.11	78.20
200 kHz	80.05	98.14	78.56
400 kHz	83.69	98.56	82.48

The use ultrasound in textile dyeing processing offers many potential advantages. Previous researching has shown that the use of ultrasonic provides saving of processing time, energy, chemicals and improvement of production quality. The results prove better dye exhaustion by ultrasound and consequently the better fixing (Fig. 3). The exhaustion for the bifunctional dye (containing two vinylsulphone groups) reaches 71.75 % without ultrasound, and 83.69 % with 400 kHz ultrasound. The 40 kHz, 150 W ultrasound causes a cavitation of higher intensity, compared to 200 and 400 kHz ultrasounds. In this particular case, destruction of cavitation bubbles is very intensive. That is why a large amount of cavitation energy is being transformed into a heat, yielding the additional bath heating. The ultrasounds with higher frequencies (200 and 400 kHz) cannot use such a strong power. The applied powering this case reaches 0.6 W. The cavitation bubbles are now smaller the cavitation disintegration is not so strong, and the energy loss is much smaller, i.e. a smaller amount of energy has been transformed into a heat. An ultrasound of an equal power, but of higher frequency contributes to the somewhat higher exhaustion and fixing.

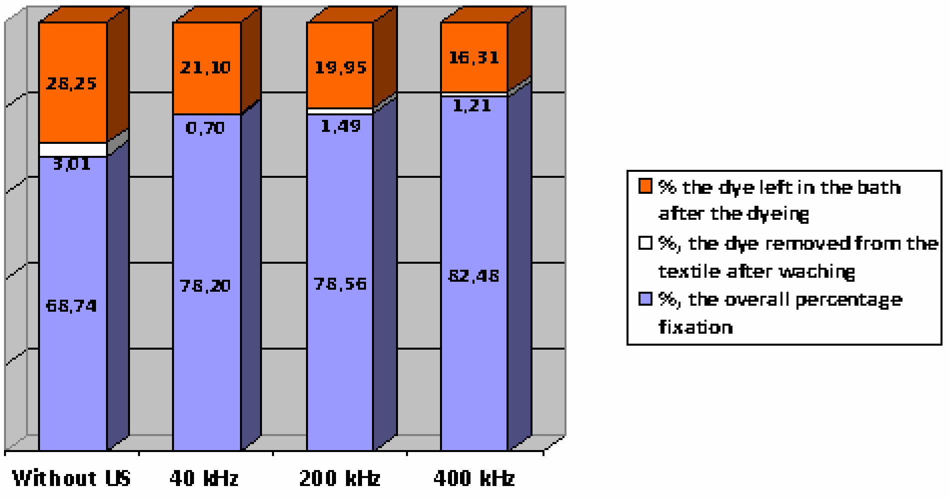

Fig. 3: *Histogram of the dye distribution between the textile substrate and the dyeing bath*

Based on the recorded reemission curves of dyed samples, computed spectral K/S values (Fig. 4) dye differences are defined according to CIELAB76 and CMC (2:1) criteria. Dyeing gained by a conventional method is used as a standard sample.

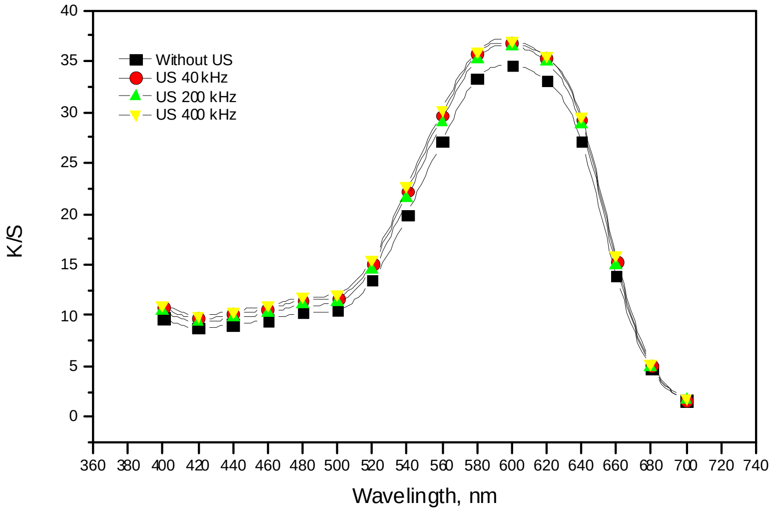

Fig. 4: *K/S values for used dye*

The ultrasound dyeing produces much obscured colours, compared the standard, table 3. The differences are evident and not negligible. The comparison of the samples treated ultrasound of different frequencies during dyeing revealed the higher coulours intensities with the increase of ultrasound frequencies of the equal power (200 and 400 kHz). However, the increase is not so expressed.

Table 3: *Colour differences of the dyed samples*
(Standard: without US, at D65 color coordinates: L=17.9; a=-3.5; b=-13.2)

COLOUR DIFFERENCES **Illuminant D65 - 10°**								
CELAB 76					**CMC (2:1) pass<1.4<reject**			
Batch	DE*	DL*	Da*	Db*	DE*	DL*	DC*	DH*
40 kHz	2.7	2.6 Darker	0.7	0.3	1.5	1.8 Darker	0.7 Weaker	0.3 Bluer
200 kHz	2.5	2.4 Darker	0.7	0.6	1.8	1.5 Darker	0.6 Weaker	0.3 Bluer
400 kHz	3.1	3.1 Darker	0.5	0.1	2.0	2.0 Darker	0.2 Weaker	0.4 Bluer

4. CONCLUSION

Ultrasonic dyeing of cellulosic fabric by means of reactive dyes has good prospects, taking into consideration the considerable dye saving for achieving a tint of equal depth in respect to conventional procedures. Moreover, it contributes largely of dye exhaustion from the tank, so that waste water pollution is considerably lower, which makes this procedure ecologically very significant.

The 40 kHz ultrasound contributes to the significant increase of the exhaustion degree as well as of the dye fixing. The increase of the ultrasound frequency accompanied the smaller power produces a higher intensity colouring (the higher depth) but overall the differences are negligible.

REFERENCES

[1] D. Sun, Q. Guo and X. Liu, (2010) Investigation into dyeing acceleration efficiency of ultrasound energy, Ultrasonics, 50, pp. 441–446.

[2] H. Wang, F. Zhaoa and J.X. Lin, (2010) Studies on the ultrasonic-assisted dyeing of poly(trimethylene terephthalate) fabric, Color. Technol., 126 pp. 243-248.

[3] V.S. Moholkar and M.M. Warmoeskerken, (2004) Investigations in mass transfer enhancement in textiles with ultrasound, Chem. Eng. Sci. 59, pp. 299–311.

[4] P.S. Vankar, R. Shanker and J. Srivastava, (2007) Ultrasonic dyeing of cotton fabric with aqueous extract of Eclipta alba, Dyes Pigm. 72, pp. 33–37.

[5] S.J. McNeil and R.A. McCall, (2011) Ultrasound for wool dyeing and finishing, Ultrason. Sonochem. 18, pp. 401–406.

[6] S.R. Shukla and M.R. Mathur, (1995) Low-temperature ultrasonic dyeing of silk, J. Soc. Dyers Colour. 111, pp. 342–345.

[7] M.M. Kamel, H.M. Helmy, H.M. Mashaly and H.H. Kafafy, (2010) Ultrasonic assisted dyeing: dyeing of acrylic fabrics C.I. Astrazon Basic Red 5BL 200%, Ultrason. Sonochem. 17, pp. 92–97.

[8] M.M. Kamel, R.M. El-Shishtawy, H.L. Hanna and N.S.E. Ahmed, (2003) Ultrasonic-assisted dyeing: I. Nylon dyeability with reactive dyes, Polym. Int. 52, pp. 373–380.

[9] A.N. Saligram, S.R. Shukla and M. Mathur, (1993) Dyeing of polyester fibres using ultrasound, J. Soc. Dyers Colour. 109, pp. 263–266.

[10] M. Vouters, P. Rumeau, P. Tierce and S. Costes, (2004) Ultrasounds: an industrial solution to optimise costs, environmental requests and quality for textile finishing, Ultrason. Sonochem. 11, pp. 33–38.

[11] A. Soleimani-Gorgani and J.A. Taylor, (2006) Dyeing of nylon with reactive dyes. Part 1. The effect of changes in dye structure on the dyeing of nylon with reactive dyes, Dyes and Pigments, 68, pp. 109-117.