Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 2, Number 1; January-March, 2015, pp. 79-82

http://www.krishisanskriti.org/jbaer.html

Ultrasonic Assisted Wet Processing

Vaibhav V. Nagaje[1] and Ashish A. Hulle[2]

[1,2]D.K.T.E. Society's Textile and Engineering Institute, Ichalkaranji-416115, INDIA
E-mail: [1]drvaibhavnagaje@gmail.com, [2]ashishhulle@hotmail.com

Abstract—*The ultrasound is one of the green approach to words green technology. Use of ultrasonic technique enhances the value of wet processing by deducting the use of energy, time, temperature and money. Because of compatibility nature of the ultrasonic technique; it able to capturing all process fields in the textiles wet processing like desizing, scouring, bleaching, mercerization and most wide field is dyeing. Use of ultrasound in the textile wet processing having some other advantages other than above mentioned, as it alters the fibre structure to increase adsorption and also raises diffusion coefficient of the chemical molecules and the dye particles in the aqueous solutions. It is found that the hydrolysis of starch in desizing is faster and completely obtained with ultra sound. The wettability and whiteness in scouring and bleaching also tremendously increased in case of ultrasonic technique. In the present scenario innovative information about use of ultrasonic technique for textile wet processing is reviewed. The physics that is held behind ultrasonic, how it is beneficial for textile pretreatments and dyeing are reviewed. Ultrasonic technique gives the alternative to the processes those are incompletes without large process assistance.*

1. INTRODUCTION

Most of textile wet process involve the use of chemicals for assisting, accelerating or retarding their rates and conducted at elevated temperatures to transfer mass from the processing liquid medium across the surface of the textile material in reasonable time. As with all chemical processes, are time and temperature dependent, and compromising either could affect product quality [1]. The use of ultrasonic energy in textile wet processing optimizes the processes. Ultrasonic desizing reduced the fibre degradation while the degree of whiteness and wet ability of the cellulosic fabric remains same. Ultrasonic scouring of wool fibres reduced the fiber damages. Similarly, in bleaching of cotton fiber with hydrogen peroxide using ultrasound technique at the frequency of 20 kHz, increased the bleaching rate and enhanced the degree of whiteness. The mercerization of cotton material using ultrasonic technique swelled 35% fiber diameter [2]. The use of ultrasonic energy in dyeing optimizes the dyeing process. Moreover, it can be used for dyeing both hydrophilic and hydrophobic fibers. Dyeing using ultrasonic technique at 50^{o}C given slightly higher color strength values than those obtained using conventional dyeing method at 80^{o}C [3]. The utilization of ultrasonic wave for cold pad-batch dyeing decreased the batching time at minimum quantity of alkali concentration. Knitted interlock fabric dyed at 600 kHz ultrasonic frequencies, temperature (30-50^{o}C) and salt concentrations 60g/dm^{3} showed deeper hue in comparison with that achieved by conventional method [4].

2. ULTRASONIC TECHNIQUE

2.1 Physics Behind Ultrasonic Technique

Sound frequency above 20 kHz is considered to be ultra sound (US). When ultrasound is applied to an aqueous solution or suspension an increase in mixing, shearing and mass transfer is observed. Under certain conditions cavitation i.e. formation of bubbles in liquid due to movement of object is produced which demonstrate itself in the production of tiny bubbles which collapses violently inward to produce so called "hotspots" which tend to generate highly reactive hydroxyl radicals and unusual chemical transformations [5].

2.2 Ultrasonic Instrumentation

The ultrasonic equipment's are an ultrasonic probe system (usually 20 kHz), an ultrasonic bath (around 40 kHz) and ultrasonic transducer (from 300-1100 kHz). Ultrasonic transducers which operate at frequencies from about 350 kHz upwards and they are classed as a High Frequency. Thus, low frequency is defined as being below 100 kHz and high frequency is greater than this value. Low frequency is between 20-100 kHz & High frequency is between 100 kHz-2 MHz [5].

3. ULTRASONIC ASSISTED WET PROCESSING

3.1 Ultrasonic Assisted Enzymatic Bio-Processing

The introduction of a low-energy, uniform ultrasound field in enzyme-processing solutions greatly improved enzyme efficiency by significantly increasing their reaction rate. It has been established that the following specific features of combined enzyme/ultrasound bio-processing of cotton are critically important: a) the cavitation effects caused by the introduction of an ultrasound field in the enzyme processing solution greatly enhance the transport of enzyme macromolecules towards the substrate surface, b) the mechanical impact, produced by the collapse of the cavitation bubbles, provides an important benefit, that of "opening up" the surface of the solid substrates to the action of enzymes, c) the effect of cavitation is several hundred times higher in heterogeneous (solid substrate-liquid) than in homogeneous systems, and d) in water, the maximum effects of cavitation occur at temperature 50^0C, which is the optimum temperature for many industrial enzymes.

Enzymatic bio-processing of cotton, like any other wet processing system, involves transfer of mass (enzyme macromolecules) from the processing liquid medium (enzyme solution) across the surface of the substrate. The detailed mechanism of enzymatic reactions, quite complicated, is still being investigated.

The overall reaction rate of enzymatic hydrolysis is governed by the diffusion rate of the enzyme macromolecules. Generally, the large three dimensional enzyme macromolecules have very low diffusion rates and also tend to react with the outlaying cellulose fibers from the cotton yarn, which could result in excessive fiber damage. It was suggested that sonication of the enzyme processing solution under certain specific conditions could provide a far more efficient transport mechanism for the "bulky" enzyme macromolecules throughout the immediate border layer of liquid at the substrate surface.

The combination of enzymatic bio-preparation and enzymatic bio-conversion of cotton waste celluloses with a low-level, uniform ultrasound irradiation could significantly advance these new "green chemistry" processes and make them more suitable for widespread industrial implementation. This could considerably reduce the amount of wastewater effluents, energy consumption and overall processing costs [6].

3.2 Ultrasonic Assisted Scouring of Wool

Wool is a keratin fibre with a complex cellular morphology. The fibres have closely packed cortical cells surrounded by single or multiple layers of cuticle cells [7]. From a macromolecular point of view, wool is a fibril-reinforced matrix material with both the fibrils and the matrix consisting of polypeptides, interconnected physically and chemically [8]. Ultrasonic wool scouring shows a variety of fibre surface modifications as a result of ultrasonic irradiation [9]. Although it was demonstrated that levels of wool cuticle disruption can be related to the ultrasonic frequency employed, it remains unknown if these ultrasound induced changes can be made to the fibre cortical cells, particularly to the micro fibrils and matrix proteins which are responsible for the many chemical and mechanical properties of the fibre [10].

3.3 Ultrasonic Treatment

Ultrasonic treatment conducted using a KQ-300VDE 10 liter ultrasonic bath (Kunshan Ultrasonic Instrument Co. Ltd., China). The bath frequency was capable of irradiating at two frequencies (45/80 kHz) with frequency sweeping. A fixed frequency of 45 kHz with frequency sweeping turned off was used. Power set at maximum of 300W for all experiments. For the fabrics to receive homogeneous irradiation each sample was placed horizontally in the bath around 5cm from the bottom in each measurement [11]. This work demonstrated an improvement in tensile strength of the fabric that is ultrasonically treated for an appropriate length of time. This is due to an increased number of regular and/or more extended protein chains within the fibre after it being ultrasonic treated, as analyzed from FTIR spectra. Ultrasonic treatment reduces fabric extensibility as treatment time increases. Prolonged ultrasonic treatment can cause both fabric strength and extensibility to decrease significantly. Wool treated with ultrasonic founds to have less mass loss and a delay in thermal degradation, in comparison with that of fabric without ultrasonic treatment and prolonged treatment time [11, 12].

3.4 Ultrasonic Assisted Dyeing

When ultrasound waves are absorbed in the liquid system the phenomenon of cavitation takes place. Cavitation can liberate entrapped gases from liquid or porous materials like textiles, dye bath etc. The influence of ultrasound on dyeing is explained to have three-way:

a. **Dispersion.** Breaking up of micelles and high molecular weight aggregates in to uniform dispersion in the dye bath.
b. **Degassing.** Expulsion (dissolved or entrapped gases or air molecules from fiber capillaries and interstices at the cross over points of fiber in to liquid and removed cavitation.
c. **Diffusion:** Accelerating the rate of diffusion of dye inside the fiber by piercing the insulating layer covering the fiber and accelerating the interaction between dye and fiber.

Way a and b are promoted by the mechanical action of cavitation, while way c is due to both the mechanical action and the heating of the fiber surface. In case of water soluble dyes, ultrasound constitutes mostly an effective means of mechanical agitation, whereas in case of pigments, which are not soluble in water, ultrasound provides means of pigment dispersion and penetration, which is not provided by the conventional method. The dyeing results are affected by the frequency of the ultrasound used. Irradiation at very low frequencies of the order of 50 or 100cps produces no effects. Frequencies in the range between 22 and 175 kHz have been found to be most effective, the latter frequency being preferable for silk, wool and nylon [13].

3.5 Diffusion of Dye Inside Fibre by Ultrasonic Technique

The diffusion of dye inside the fiber is speeded up in the ultrasonic field. The speed of dye diffusion inside the fiber depends upon the size of the dye molecular and the state of the fiber i.e. the smaller the dye molecule and greater the fiber swelling the higher is the mobility of the dye molecules and the quicker they penetrate inside the fiber. Another factor, which influences the diffusion of dye inside the fiber, is its activated state. The dye diffuses in the fiber pores, which are full of water and at the same time it is adsorbed by the adjacent macromolecules. Owing to adsorption only a small part of dye can freely move inside. The dye molecules spent much of their time in vibrating to and fro before they are adsorbed on the surface. Because of the simultaneous adsorption and diffusion, the diffusion slows down if the rate of adsorption is slow. However, because of the intense cavitation force in the ultrasonic field the dye molecules arrive at the fiber surfaces at a much faster rate as they gain additional kinetic energy. The dye must be in the activated state to diffuse. This activated state to be brought about by ultrasonic energy, which furnishes the vibrating molecules with the critical energy they need to break their static equilibrium and thus to diffuse. Pressure of the ultrasonic radiation on the surface of the fiber is another factor, which influences the diffusion process. There may be some loosening in the crystalline structure although most transient but of great significance in speeding up the rate of diffusion. Therefore, dyeing carried out at low temperature in the ultrasonic field showed adsorption equivalent to that in dyeing carried out without ultrasound at higher temperature [13].

3.6 Ultrasonic Assisted Instrumentation for Dyeing

Ultrasound generator and converter are the two main components of ultrasound equipment. Generator converts 50 to 60 Hz alternate current to electrical energy of high frequency. This electrical energy is fed to the transducer where it is transformed to mechanical vibration. The transducer system vibrates longitudinally transmitting waves into liquid medium. As these waves propagate cavitation occurs. Prototype dyeing machine was designed for continuous dyeing of yam and fabric. The system mainly consists of the tank, transport system and microprocessor, which is used to monitor the process. Ultrasonic tank is of 92 x 60cm dimensions and capacity up to 200liters. Temperature can be varied up to 100°C by thermostatic control [13].

3.7 Ultrasonic Assisted Washing of Textile

The use of the ultrasonic technology in cleaning textiles and aiming to the development of such industrial applications, a new procedure was developed and patented in which the textiles are exposed to the ultrasonic field in flat format and within a thin layer of liquid by applying specific plate transducers. Such process has been implemented at semi-industrial stage. Washing tests carried out with typical textile samples (EMPA-101) shows that the cleaning performance achieved (measured through the reflectance) even at relatively moderate acoustic intensities is more than double that obtained with a conventional washing machine while the energy consumption is very low (of the order of 0.1kWh/ kg of textile) [14].

4. MERITS AND DEMERITS OF ULTRASONIC TECHNIQUE

4.1 Merits of Ultrasonic Technique

Benefits of ultrasound in textile processes may include savings in energy, reduction in consumption of chemicals and/or dyes, and reduction in process time. Among all wet processes, application to the dyeing process seems to be most advantageous, washing being the least expensive process. Another important aspect of today's concern is the possibility of reducing the pollution load on effluent water. Increased mass transfer from liquid to textile substrate leads to two possibilities: (i) increase in add-on, or (ii) less dosage of dyes or chemicals to the bath to obtain equivalent add-on to the substrate. In either case, the concentrations of pollutants in water would decrease. A final benefit might be the potential for controlling process rates with ultrasound as a substitute for chemical accelerators and retarders [16].

4.2 Demerits of Ultrasonic Technique

No significant commercial installations have been developed to date for the following reasons:

a. Applying ultrasound to a bath is expensive, and environmental problems have not been a significant concern until recently.
b. The ultrasound waves may be less predictable with production size equipment.
c. Intensity of the wave could vary with production size equipment [16].

5. CONCLUSION

Ultrasonic technique is an environmentally user friendly and sustainable technique for saving process assistants, time and temperature. Not only economical point of view the ultrasonic technique beneficial but also from quality of the processed product, effluent load and most important compatibility point of view have the valuable important. That means the Ultrasonic technique is the green alternative to other techniques because of its bundle of benefits and compatibility. In other words to put the one step to words green technology, environmental friendly techniques, ultra sound technique is able to give diversification to the conventional technique. In one line for ecofriendly textile processing ultrasonic is better alternative to existing techniques.

REFERENCES

[1] Mathur, M.R., Sankhe, M. D. and Bardhan, M. K., "Energy Conservation in Wet Processing: Developments of Low Energy Dyeing Machine", *The Synthetic and Art Silk Mills' Research Association*, Worli, Mumbai-400030.

[2] Yan, G., Zhang, M., "Ultrasonic Wool Scouring Process", *Journal of Textile Research*, 27, 10, 2006, pp. 96-98.

[3] Ahmed, N.S., Shishtawy, R.M., and Kamel, M.M, "Ultrasound Assisted Pre-treatment and Dyeing of Linen Fibres with Reactive Dyes", *Pigment and Resin Technology*, 36, 1, 2007, pp. 363-372.

[4] Syed, U., Samad, A.and Ahmed, F., "Dyeing of Organic Cotton Fabric using Conventional and Ultrasonic Exhaust Dyeing Method", *Mehran University Research Journal of Engineering and Technology*, 32, 2, April 2013, pp. 329.

[5] Kwiatkowska, B., Bennett, J., Akunna, J., Walker, G. M. and Bremner, D.H., "Stimulation of Bioprocesses by Ultrasound", School of Contemporary Sciences, University of Abertay Dundee, Bell Street, Dundee, DD1 1HG, UK.

[6] Condon, B., Eason, M., Yachmenv, V., Lambert, A., Delhom, C. and Smith, J., "Application of A Low-Level, Uniform Ultrasound Field for the Acceleration of Enzymatic Bio- Processing of Cotton", *Cellulose Chem. Technol.*, 43, 9-10, 2009, pp. 443-453.

[7] Bradbury, J.H., "The structure and chemistry of keratin fibres, in Advances in protein chemistry", *Academic Press: New York, 1973*, pp. 111-211.

[8] Simpson, W.S., Crawshaw, G. H., "Wool: Science and Technology", *Woodhead Publishing limited in association with the Textile Institute*, Published by CRC Press, New York USA, 2002.

[9] Li, Q., Hurren, C. J. and Wang, X.G., "Cuticle Modifications and Dyeing property of Ultrasonically Scoured wool", *Proc. of 12th International Wool Research Conference*, Shanghai, China, October 20 2010, pp. 77-80.

[10] Li, Q., Hurren, C. J., Wang, L.J., Lin, T., Yu, H.X., Ding, C.L. and Wang, X.G., "Frequency dependence of ultrasonic wool scouring", *Journal of Textile Institute*, 102, 6, 2011, pp. 505-513.

[11] Perincek, S., Uzgur, A.E., Duran, K., Dogan, A., Korlu, A., and Bahtiyari, I.M., "Design parameter investigation of industrial size ultrasound textile treatment bath", *Ultrasonics Sonochemistry*, 16, 2009, pp.184-189.

[12] Qing, L.I., Hurren, C.J., and Wang, X., "Changes in Wool Protein Structure and Fabric Properties with Ultrasonic Treatment", *Smartex Research Journal*, 1, 1, March 2012.

[13] Saravan, D., "Ultrasonics Assisted Textile Processing-an Update", *Colourage*, 53, 4, 2006, pp. 111-116.

[14] Juan, A. and Gallego, J., "High-Power Ultrasonic Processing: Recent Developments and Prospective Advances", *International Congress on Ultrasonics*, Santiago de Chile, January 2009.

[15] Gallego-Juárez, J. A., Nájera Vázquez de Parga G., Rodriguez Corral G., Vazquez Martinez F., Van der Vlist P., "*Process and Device for Continuous Ultrasonic Washing of Textiles*", U.S. Patent, No. US 6,266,836 B1, July 31 2001.

[16] "Application of Ultrasound in Textile Wet Processing Phase 1", *North Carolina State University Raleigh*, North Carolina.