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Comparison of conventional and ultrasonic method for dyeing of spunbond polyester nonwoven fabric

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ABSTRACT

Nonwoven spunbonded polyester has wide applications for both household goods and home furnishings and their usage has continually been growing. Nowadays, coloration of nonwoven fabrics is performed using conventional methods. Conventional polyester dyeing is an energy-intensive process as the dyeing is carried out above 120 °C to obtain efficient diffusion of dye. Furthermore, these high temperatures may cause some harmful effects on delicate nonwoven structures. Ultrasound assisted textile dyeing is an alternative method of conventional dyeing of textile materials, providing energy saving by reduced process temperature and time, lower consumptions of auxiliaries with increased dyeing efficiency. This paper focuses on comparing the conventional (high temperature (HT) and carrier dyeing) and ultrasonic dyeing of nonwoven spunbonded polyester fabrics to investigate the effect of ultrasound energy on dyeing performance. Experimental results indicated that highest or comparable dyeing performance can be achieved with ultrasound dyeing at lower temperature (85 °C, 60 min.) without carrier as compared to carrier dyeing (100 °C, 60 min.) and HT dyeing (130 °C, 60 min.), providing an increase of dye depth depending on the dye concentration and basis weight of the fabric. It was evidently seen that highest basis weight of fabric (107 g/m^2) used in this study exhibited greater color yield for each dye concentrations (K/S value of 4.90 at 0.2% dye concentration) as compared to conventional ones. The effect of ultrasound energy on reductive washing and fastness properties were also evaluated.

1. Introduction

Spunbond polyester nonwoven fabrics have increasingly been used for both household goods and home furnishings, such as draperies, furniture upholstery, mattress padding, towels, table cloths, bed linen, blankets, carpet backing and for clothing and apparel, such as for caps, linings, interlinings, interfacings and the reinforcement of other fabrics. Nowadays, thermal bonding is one of the most widely used technologies to produce nonwovens. It provides energy saving because of more efficient thermal contact and no water needs to be evaporated after bonding. It is also environmentally friendly since no residual needs to be disposed of. In thermally bonded spunbond formation, fibers are bonded exclusively by utilizing their thermoplastic character. Under controlled heating, fibers are bonded together by means of thermally fusing part of the fibers/filament surfaces. Thermal-bonded nonwovens are usually softer and drier, have superior strength per unit weight, good water and air permeability since they have very smaller bonding points [22,25–27].

Nowadays, coloration of all type of nonwovens is performed using conventional methods. Nonwoven fabrics composed of conventional fibers can be dyed to a deeper shade than woven or knitted fabrics of the same composition and have a greater accessible fiber surface area because of the high permeability and absence of twisted yarns and yarn intersections in the fabric structure. Conventional dyeing of spunbond polyester fabrics requires above 120 °C to obtain efficient diffusion of dye since polyester fiber structure is too compact to allow simple chemicals to enter inside below its glass transition temperature (Tg ~ 85 °C). Polyester is hydrophobic, non-ionic and dyeable almost only disperse dye [13–17]. So that when it is necessary to dye polyester fibers and blends under atmospheric conditions, carriers are used to swell the polyester fibers, increase inter polymer space and let the dye to enter the polymer easily at atmospheric conditions. But unfortunately, the undesirable carrier residues remain on the fabric surface after treatment and they are generally toxic. In addition, these temperatures and dyeing conditions cause some harmful effects on delicate nonwoven structures.

However, bonded and unbonded regions of the thermal-bonded spunbonds have significant morphological differences. Crystal sizes show differences in the bonded and unbonded regions, with the values being higher in the bonded areas. This is due to the effect of heat in the

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bonded region. Bond area increases with increase in bonding temperature. Within the bonded areas, the crystal sizes are slightly affected or remain in the same range by bonding temperatures. Differences of crystallinity (often referred to as fiber morphology) of thermal-bonded spunbonds is of critical importance when considering the possibility of color uniformity by dyeing [22–31]. In order to develop dye uptake and migration of dye molecules from dyebath to fiber, accordingly improving the dyeing uniformity of thermal-bonded polyester spunbonds without any degradation problem, it is needed to design moderate dyeing conditions for nonwoven fabrics.

Ultrasound assisted textile dyeing is an alternative method of conventional dyeing of textile materials, providing energy saving by reducing the dyeing times & temperatures and consumptions of auxiliaries with increased dyeing efficiency. Ultrasonic energy seems potentially beneficial to the application of water insoluble dyes to the hydrophobic fibers [13,17,12–20]. It has been used in dyeing polyester with disperse dyes at lower temperatures and short process times in comparison to conventional dyeing. Ultrasound is an oscillating sound wave, which emits the frequencies of 18 kHz–10 MHz beyond human hearing. Ultrasonic waves are high frequency longitudinal waves that propagate into the materials and so it was assumed that they have an effect on the rate of dyeing [1–11]. In liquid, high-frequency waves cause the formation of microscopic bubbles, or cavitation. During dyeing in an ultrasonic bath, the rapid movement of the liquor is observed due to variation of sonic pressure, which subjects the liquor to compression and rarefaction and micro steaming. Simultaneous formation and deflation of micro bubbles, known as cavitation, result in an increase in local high temperature, high pressure and shock wave occurrence in the dye bath at microscopic level. This induced heat is generally adequate for wet processing and thus decreases the need for external heating, accompanied by improved product quality. [1–3,12–17]. In addition, ultrasound provides pigment dispersion and penetration, which are not provided by the conventional method since it causes to increase aqueous solubility of disperse dye particle and help uniform dispersion of the dye aggregates in the bath, reducing mean particle size of disperse dye [13,17,12–20].

Although dyeing with disperse dyes using ultrasonic bath has been discussed by several authors, limited research has been reported on ultrasonic assisted polyester dyeing. Lee et al. [21] studied the influence of ultrasound on changes in dye particle size and the specific breakage rate of disperse dyes with different crystalline properties. The results showed that the breakage of dye particles strongly depended on the liquid medium temperature, the ultrasound intensity, and the dye dispersion volume [21]. In another study, Lee et al. [22] investigated the influence of ultrasound on the dyeing behavior of PET fibers. They reported that the application of ultrasound in the dyeing process more enhanced the dye uptake and dyeing rate for highly crystalline structured dyes than the poor ones [22]. Burkinshaw et al. [23] focused on the effects of ultrasound on the dyeing of poly(lactic acid) with six disperse dyes. It was reported that dyeing at 80 °C in the presence of ultrasound resulted in pale, dull dyeings of reduced color strength for five of the dyes used, which was attributed to breakdown of the dye dispersions at this particular temperature [23]. Kodric et al. [24] reported the modelling of disperse dye adsorption in the presence of ultrasonic waves. Efficiency of dyeing was found to be depended on the time of contact, initial concentration of the dye and the amount of absorbent material. The continuity of growth in the amount of exhaustion dye with mass of material was observed [24].

Due to the increasingly popular use of spunbonded polyester nonwovens from the household goods to home furnishing sector, in this study, ultrasonic dyeability of spunbond polyester nonwoven fabric was investigated. Nowadays, coloration of nonwovens are performed using conventional methods, either batch or continuous system and, until now, ultrasound dyeing of spunbond nonwovens has't been reported yet. Designing a new ultrasonic dyeing process that improves dye uptake, fastness properties and dyeing uniformity of polyester nonwoven at low dyeing temperature will ensure total energy saving with improved fabric quality. However, ultrasonic bath has a limitation of excessive heating of crystal transducers while working at a temperature above 85 °C. Therefore, experiments were carried out at 85 °C or below it. Results were compared to HT and carrier dyeing methods to determine the appropriate process condition for ultrasound assisted spunbond polyester dyeing. Colored samples were evaluated by using Datacolour spectrophotometer for CIE Lab (L^*, a^*, b^*, ΔE^*), and K/S values and tested for rubbing, washing and water fastness properties using relevant ISO standards [32–35]. The UV–VIS spectrophotometer was used for measuring the absorbance of dyeing solutions. Reductive washing was applied to the samples using conventional method (80 °C, 15 min) and ultrasonic method (in ultrasonic bath at reduced temperature and time). The effects of ultrasonic and conventional method on reductive washing were also investigated in terms of CIE Lab (L^*, a^*, b^*, ΔE) and K/S values of samples and absorbance values of washing baths. The effects of process parameters (basis weight of fabric, dye concentration, dyeing method) on dyeability of spunbond nonwoven fabrics were also studied by evaluating of K/S values using minitab 17 statistical software program.

2. Experimental

2.1. Materials

In this study, thermally bonded spunbond polyester fabrics with three different basis weight (20 g/m^2, 35 g/m^2, 107 g/m^2) were used and provided by General Nonwoven Co. Ltd (Turkey). Medium-energy disperse dye with medium molecular weight (C.I. Disperse Red 50, C.I.11226, Mw = 357.8) suitable for exhaust polyester dyeing was used and supplied by Setaş Kimya Co. Ltd, Turkey (see Fig. 1).

Anti-creasing agent (Setalub Aca), leveling agent (Setalan DFT-NEW), dispersing agent (Setalan SW), acid regulator (Setacid PBN-2), carrier (Setacarrier HT) and reductant agents were also supplied by Setaş Kimya Co.

2.2. Dyeing process

Setapers Scarlet 2GH-Conz Red was applied to spun-bond polyester nonwoven fabrics at 0.05% – 0.1% – 0.2% concentrations according to the supplier's procedure.

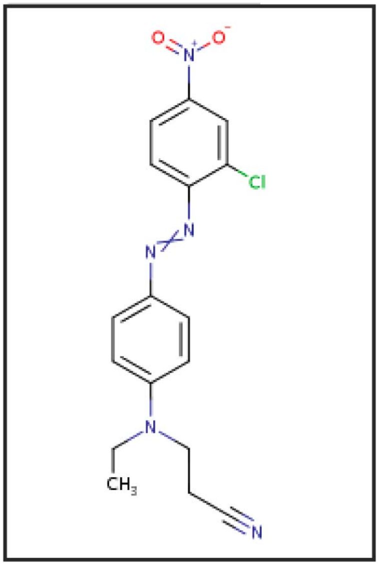

Fig. 1. Setapers Scarlet 2GH-Conz Red. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)