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Examination of the dyeing properties of pigment printing fabrics in a water-ethanol mixed solvent

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ABSTRACT

We examined the dyeing properties of pigment printing fabrics in a water-ethanol mixed solvent. SEM, infrared spectroscopy, XRD, and rheological studies were carried out to understand the results. The K/S values of all pigment printing fabrics initially increased prior to a subsequent decrease, as can be observed from SEM images of the fabric surfaces. Viscosity tests indicated that variations in the dyeing performance in the mixed solvent could be mainly attributed to the quality of the thickener. Through examination of the rheological properties of the NaAlg paste and the IR spectra of the NaAlg membrane, ethanol appeared to weaken the hydrogen bonds between the NaAlg chains and water molecules, leading to more compact and disordered NaAlg chains. As the rubbing fastness remained relatively constant upon increasing the colour depth of the printing fabrics, this indicated the potential for broadening the application range of such a system.

1. Introduction

Pigment printing is a rapid dyeing process with several advantages, including its easy application to a variety of fibres, its relatively environmentally friendly nature, and its comprehensive colour range. As such, pigment printing has been employed in textile printing for a number of decades, becoming more important following the discovery of emulsion thickening, which dates back to the 1930s (Schwindt & Faulhaber, 1984). However, its application has been restricted due to difficult handling and poor colour fastness, in particular for the use of dark colours (Abdou, Hakeim, El-Gammal, & El-Naggar, 2009).

A number of efforts have been made to solve these issues in the context of fabric, pigments, and auxiliaries (Ibrahim, El-Zairy, Allam, & Hassan, 1996; Ibrahim, El-Zairy, Zaky, & Borham, 2005). For example, cationic pre-treatment of the fabrics involves the introduction of a positive charge onto the fabric surface, which then attracts pigments bearing a negative charge. El-Shishtawy studied the anionic dye and pigment printing properties of cotton fabrics following cationic pre-treatment, and reported improved fastness properties (El-Shishtawy & Nassar, 2002). In addition, Wang examined the modified pigment printing properties of cationic pre-treated cotton fabrics, reporting an improvement in the colour strength (Wang & Zhang, 2007). An alternative technique involves the development of ultrafine pigments (50–220 nm), whose tinting strength, brilliance, and cover are superior to ordinary pigments. Furthermore, Wang et al. studied the superfine pigment dyeing properties of silk, cotton, and acrylic fabrics, with all reporting increased colour depth, improved colour fastness, and enhanced levelling properties (Fang, Wang, Zhang, & Xu, 2005; Wang, Fang, & Ji, 2007; Wang, Wang, & Wang, 2013). Moreover, the binder quality also plays an important role in the dyeing properties of pigment printing fabrics. While Maris studied the effect of crosslinking on the printing properties (Maris, Iqbal, & Aleem, 2009), Gao prepared a cationic binder via a surfactant-free emulsion polymerisation method, resulting in improved wet and dry rubbing fastness (Gao & Feng, 2014).

Solvent dyeing was first reported in the 1950s to avoid the issue of water pollution arising from traditional dyeing processes, and has been mainly applied to synthetic fibres. Stevens et al. studied the direct and reactive dyeing properties of cotton fabric in a water-butanol mixed solvent (Steven & Peters, 1957), while Silver et al. discussed the direct and reactive dyeing properties of cellulosic fibres in a water-glycol tetrachloroethylene emulsion (Silver, 1974). In addition, Ferrero et al. investigated the direct and reactive dyeing properties of cotton, wool, and polyester in an ethanol-

Abbreviations: IR, infrared; NaAlg, sodium alginate; SEM, scanning electron microscopy; XRD, X-ray diffraction.

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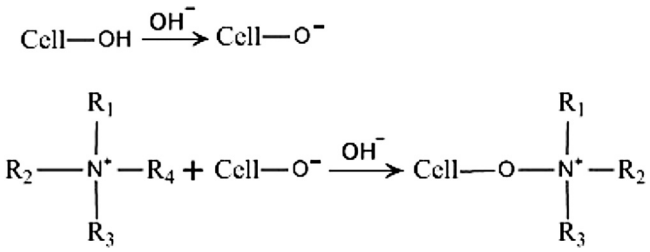


Scheme 1. Modification mechanism of cationic modification agent.

glycerol mixed solvent (Ferrero & Periolatto, 2012, 2011). In all cases, an enhancement in the dyeing properties was observed.

Thus, in light of the excellent improvements in the dyeing properties of conventional processes using organic solvents, we herein examine the dyeing properties of pigment printing fabrics in a water-ethanol mixed solvent. These studies will be undertaken with the aim of determining a cheap and convenient method for improving pigment printing properties. In addition, a range of analytical techniques will be employed to interpret the dyeing results, including scanning electron microscopy (SEM), infrared (IR) spectroscopy, X-ray diffraction (XRD), and analysis of rheological properties.

2. Experimental

2.1. Materials

Mill scoured, bleached plain weave cotton fabric (112 g/mm^2) purchased from Anhui Huamao Textile Co. Ltd, China was used throughout the study. Half of the fabric was immersed in cationic modified fluid (Hansi GRE, Jiangsu Hannuosi Chemicals Co. Ltd, China), whose active ingredient is a kind of quaternary ammonium compound, and its effect principle is to impart fabric with positive charge o induce the affinity between pigments and fabric, as shown in Scheme 1.

The manufacturing process was as follows:

original fabric → modified solution (a mass fraction of 3%) impregnation → double-nip-double-dip padding process → drying (80 °C, 10 min).

C.I. Pigment Red 170 paste, C.I. Pigment Yellow 81 paste, and C.I. Pigment Blue 15:3 paste (see Scheme 2) were supplied by Shanghai Silian Ink Chemical Co. Ltd, China. Helizarin Binder UDT was provided by Guangzhou CHF Chemical Co. Ltd, China. The sodium alginate thickener and ethanol, purchased from Sinopharm Chemical Reagent Co. Ltd., China, were of reagent grade.

2.2. Pigment printing

The composition of the water-ethanol mixed solvent pigment printing paste is as follows: 50 g/kg pigment paste, 200 g/kg binding agent, 2 owf% NaAlg, X distilled water, and Y ethanol, where X and Y vary depending on the desired water-ethanol ratio. The paste was prepared by stirring the pigment paste, binding agent, and the desired amount of water (determined according to the water/ethanol ratio), followed by the slow addition of sodium alginate (NaAlg) into the liquor under air at 20–25 °C. Upon complete gelatinisation of the NaAlg (i.e., the formation of a smooth, homogeneous paste over ~30 min), the desired amount of ethanol (X:Y mass ratios of 10:0, 9:1, 8:2, 7:3, and 6:4) was then added. Finally, the printing paste was obtained by stirring to give a homogenous mixture.

The printing paste was then applied to fabrics through a flat screen. The manufacturing process was as follows:

original fabric/cationic modified fabric → scraping paste → predrying (80 °C, 10 min) → baking (150 °C, 3 min).

2.3. Preparation of sodium alginate paste and sodium alginate membrane

The NaAlg stock solution was prepared by slow addition of the thickener to distilled water. When NaAlg reached full swelling, the desired amount of ethanol (see ratios defined previously) was then added. The desired NaAlg paste was obtained by stirring all ingredients to give a homogenous mixture. The final NaAlg membrane was acquired by drying the NaAlg paste (100 g) at 80 °C in a watch glass.

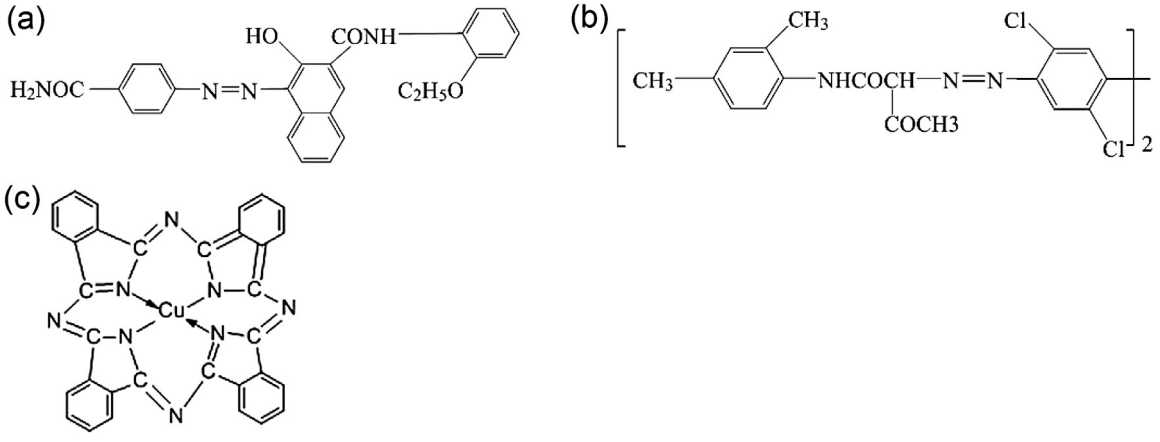
2.4. Characterisation

The colour strength (K/S value) was measured using a Color i7 Colour Matching System (X-Rite, USA) with a 10° standard observer and D65 illuminant. The equation $K/S = (1R)^2/2R$ was employed for these measurements, where K/S is the ratio of the absorption and scattering coefficients, and R is the reflectance at the maximum absorbance wavelength of the pigment colorants.

Rubbing fastness (GB/T 3920-2008 [15]) was tested on a rubbing tester (Y571N; Hongda Experimental Instrument CO., Ltd, China).

In addition, the air permeability of the printing fabrics was determined on a YG461E-III fully automatic air permeability tester (Ningbo Textile Instrument Factory, China).

Furthermore, the viscosity of the printing paste was measured using a NDJ-8S digital viscometer (Fangrui Instrument CO., Ltd, China) at 20 °C under a relative humidity of 65%.



Scheme 2. Molecular formula of the pigments: (a) C.I. Pigment Red 170; (b) C.I. Pigment Yellow 81 paste; (c) C.I. Pigment Blue 15:3.