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The influence of the mechanical rub process on the color change of thermochromic prints on textile samples

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Introduction

Thermochromic inks change colour in response to temperature variations and contain microencapsulated thermochromic pigments in a binder. These inks can be reversible, changing colour multiple times, or irreversible, changing colour only once (Tamrin et al., 2022; Jamnički Hanzer et al., 2023). They offer aesthetic appeal and functionality for applications in fashion and protective clothing (Strižić Jakovljević, 2022). Monitoring material resistance to mechanical damage is crucial for durability, as it affects both functional and aesthetic properties (Jamnički Hanzer et al., 2020). This research aims to study the impact of mechanical rubbing on the colour change rate of thermochromic inks on textiles, evaluating their durability and potential for the textile industry.

Methods

Using a manual screen-printing technique, reversible thermochromic magenta ink based on leuco dyes was applied to white textiles of different raw material compositions, ensuring high contrast. Six samples were examined, three for each type of textile material, and subjected to various rubbing cycles to assess the durability of the ink. To activate the ink, the samples were heated on a stone plate at 50°C for two minutes, then cooled and measured for color changes over time using thermal, spectrophotometric, and colorimetric tests. The color difference between the samples before and after rubbing was calculated using the CIE ΔE2000 formula. Spectrophotometric analysis measured reflectance at wavelengths between 400 nm and 700 nm to quantify color changes caused by rubbing. The measurements were interpreted against visual perception to evaluate the quality and durability of the thermochromic ink. A Testex FT411 device was used to test the color fastness of the prints after multiple rubbing cycles. Ambient conditions during testing were 22°C ± 2°C, 40% ± 2% humidity, and 101 kPa ± 1 kPa atmospheric pressure.
The samples were printed with a 120 l/cm printing screen, on white textile materials with different raw compositions: 100% polyester, 0.405 mm fabric thickness and 168.4 g/m^2 fabric weight (Sample 1) and 100% cotton, 0.405 mm fabric thickness and 150.2 g/m^2 fabric weight (Sample 2). Each sample measures 18 x 9 cm, with a printed field of 14 x 3 cm. Three samples were prepared for each material type. The white substrate was chosen for its good contrast with the magenta print.
Magenta reversible thermochromic water-based leuco ink, with an activation temperature of 31°C, was used for printing all samples on various substrates, including textiles. The ink consists of a binder and pigment, mixed in a 50:50 ratio. After printing, the samples were dried for 2 minutes at 160°C in a COLO DRYS53A multifunctional device (SFXC, 2023).

Results and Discussion

Temperature measurements for both samples were taken at intervals before and after three rubbing cycles of 20 repetitions each (0, 20, 40, 60). The study found that mechanical damage, such as repeated rubbing, minimally impacts the average temperature change of thermochromic prints on textile samples during cooling, with differences around 1°C between conditions. However, as the number of rubbing repetitions increases, the rate of temperature change decreases, and Sample 2 consistently reaches the activation temperature faster than Sample 1 across all tested conditions.
Figures 1 and 2 showes the colour difference values for Sample 1 before and after three rubbing cycles, during a time interval of 120 seconds.

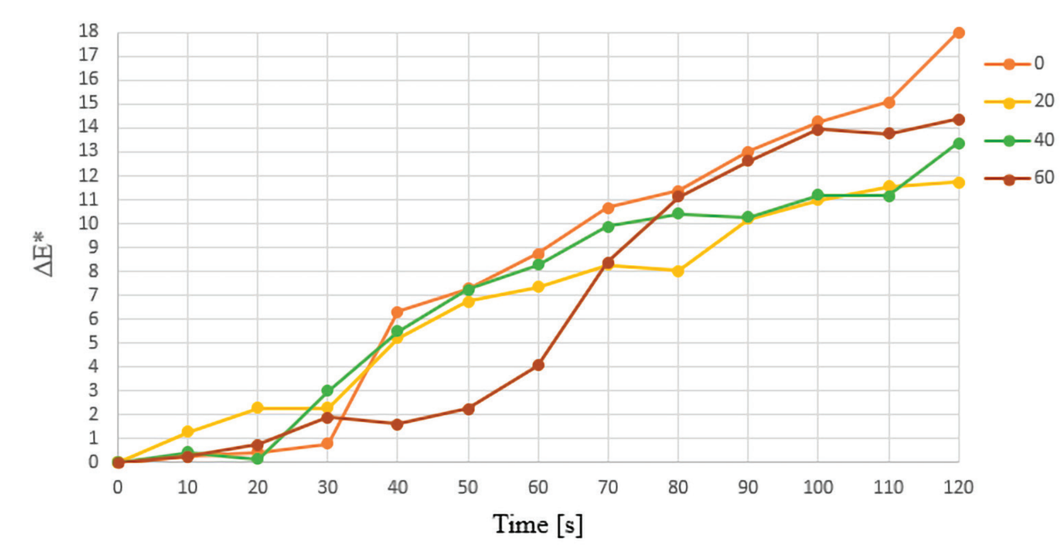

Figure 1.

Comparison of absolute color difference over time for Sample 1 before and after three rubbing cycles.

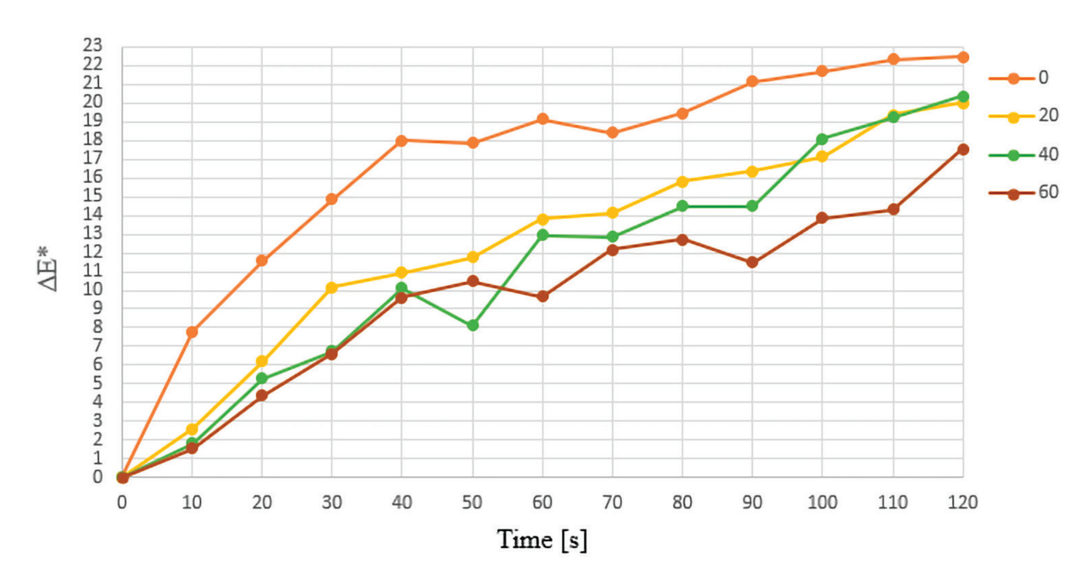

Figure 2.

Comparison of absolute color difference over time for Sample 2 before and after three rubbing cycles.

For both samples, the largest color differences were observed before the rubbing process, with gradual increases as temperature dropped below the activation point. Sample 2 showed that rubbing cycles slightly influenced color change values during measurement, with visible but acceptable differences, especially around the activation temperature.
Spectral reflectance analysis (Figure 3) of Sample 1 showed no overall decrease in reflection after three dry rubbing cycles, but reflectance at the activation temperature decreased as rubbing increased, with a slight deviation in the final cycle.

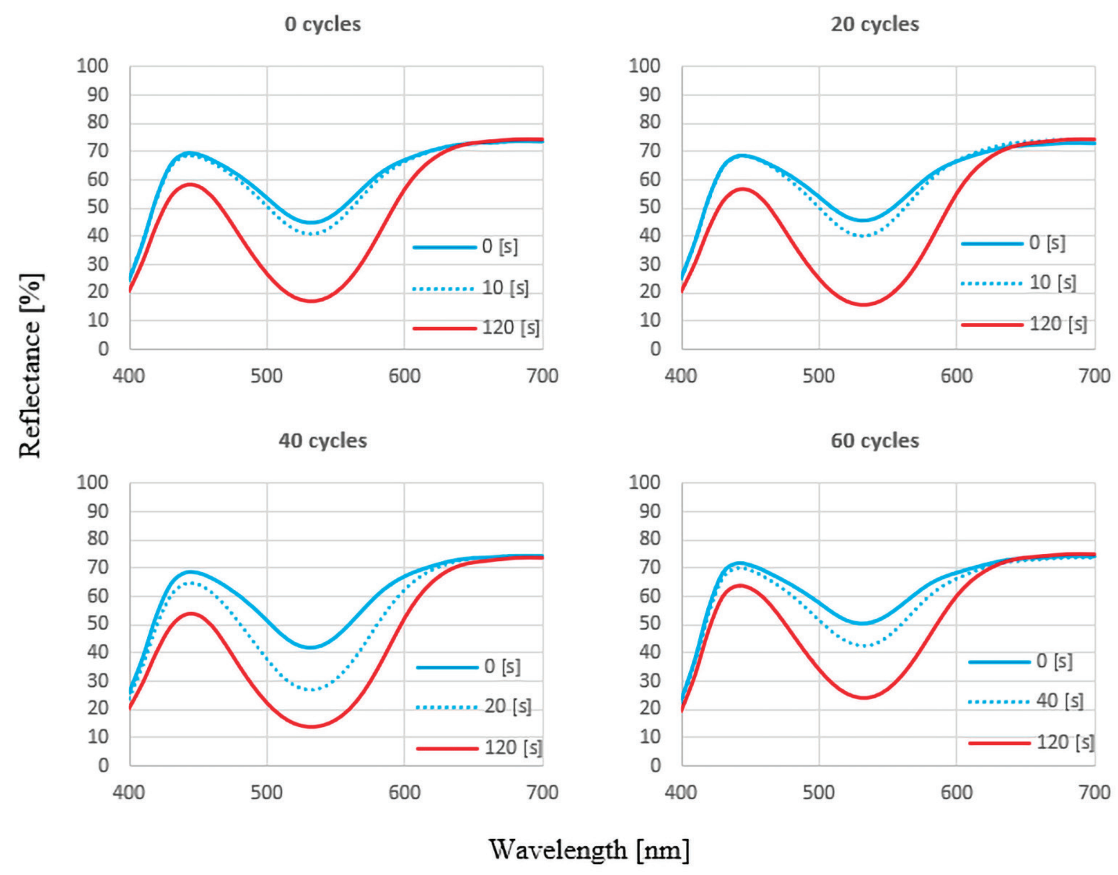

Figure 3.

Comparison of maximum and minimum spectral reflectance for Sample 1

Figure 4 shows that spectral reflectance od Sample 2 decreases with each rubbing cycle, aligning with thermal measurements as thermochromic color returns, indicating a relationship between reflectance and rubbing repetitions.

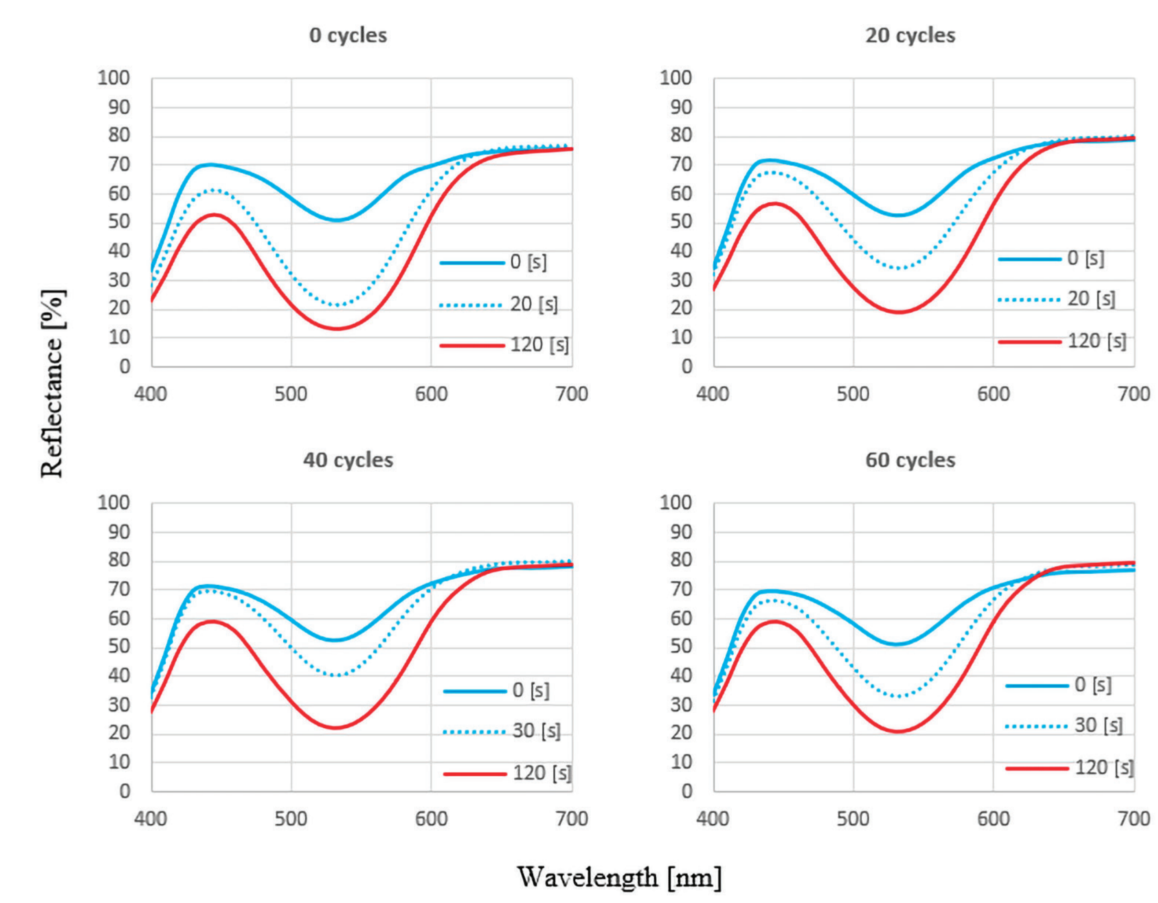

Figure 4.

Comparison of maximum and minimum spectral reflectance for Sample 2

Conclusion

The study examined the impact of rubbing and friction on the colour change of thermochromic dye on polyester and cotton samples. Cotton showed slight degradation from rubbing, indicating its sensitivity to physical influences, while polyester displayed no significant colour change with increased rubbing cycles, suggesting higher resistance to abrasion. These findings suggest polyester is more suitable for applications involving intense rubbing, while cotton is better for less demanding conditions. Future research could focus on improving cotton's rubbing resistance or developing material blends that combine the strengths of both fabrics.

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