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Possibilities of Dyeing of Polyamide Fabric with Substantive Dye

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Abstract: The possibility of dyeing polyamide fabric with a substantive dye is studied in this paper. This type of dye most often dyes natural fibers, e.g. cotton, while polyamide belongs to the group of synthetic fibers. Due to their outstanding mechanical properties, polyamide fibers are used in the production of clothing, technical textiles and reinforcement of textile composites. Dyeing by substantive dye is performed with the aim of applying it in industrial conditions. Substantive dye can be bonded by hydrogen bridges with amide groups in a polyamide chain. 100 % polyamide 6.6 fabric was used. The samples were dyed at temperatures of 95 °C with the addition of acetic acid. Samples were dyed at a time interval of 5, 10, 20, 40, 50, and 60 minutes. The solution contained dye concentrations of 5, 10, 15, 20, 25 and 30 mg/dm^3. From the results, the degree of dye exhaustion and adsorption capacity were analyzed. At the highest applied dye concentrations and the longest dying time, the highest adsorption occurs. Increasing the concentration of dye when dyeing PA 6.6 fabric with a substantive dye reduces the degree of exhaustion, longer dyeing gives a higher degree of dye exhaustion, and this is maintained throughout the dyeing process. The adsorption capacity increases during the increase of the initial dye concentration and time, i.e. a larger amount of dye or a longer period of dyeing yield a higher amount of adsorbed dye per unit mass of polyamide fabric.

Keywords: Polyamide, Dyeing, Adsorption, Substantive dye

Introduction

The most often used polymers in the textile industry are polypropylene, polyacrylonitrile and polyamide. These fibers surpass the production of natural fibers. Advantages of the chemical fibers are strength, wear and stretch resistance, relatively low price and easy recycling. In addition to their useful properties, they also have disadvantages such as hydrophobicity, less wearing comfort, poor color fastness and a number of difficulties in finishing work (Parvinzadeh, 2012).

Due to their outstanding mechanical properties, polyamide fibers are used in the manufacture of clothing, technical textiles and reinforcement of textile composites. Polyamide fibers have a very smooth surface with a low surface area energy. Physical and chemical methods are used to improve surface properties such as humidity, biocompatibility and color sorption (Rietzler, Bechtold, & Pham, 2018). Substrate dyeing is performed in a neutral or acidic bath depending on the affinity of the dye and the depth of the shade which is to be achieved. Substrate dyes exhibit dichroism on polyamide, indicating that dye molecules are bound hydrogen bridges with amide groups in the polyamide chain (Džokić, 1989, Novaković, 1996). Substance dyes are chemically composed of sulfonated azo compounds: derived from benzidine and its derivatives or amines of the diaminostilbene type, etc. Substantive dyes are soluble in water and their solubility depends on the chemical composition, especially from the content of sulfone groups in the molecule. Solubility increases by raising the temperature of the solution, and when the temperature is lowered, a stable solution (Novaković, 1996). is obtained. Substantive colors are very popular because they have exceptional advantages such as a wide range of

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colors, low prices, excellent color penetration, short staining time, etc. However, they also have disadvantages such as poor durability washing due to hydrophilic sulfone groups in the structure of molecules (Liu, Wang, & Xu, 2010).

In this paper, new findings from the laboratory research of dyeing polyamide 6.6 fabric are presented with a selected substrate dye that has a high affinity for this fiber, in a slightly acidic bath without additives. The aim of the research is to develop a procedure for dyeing polyamide 6.6 with direct dye without the addition of any substances aqueous dye solution in laboratory conditions with a tendency to be applied in industry, given that this dyeing is not common for polyamide dyeing.

Method

In the experimental part, 100% raw polyamide 6.6 fabric was used. One measurement was performed for each of the samples. The dyeing was performed in glass conical flasks in which a sample of raw polyamide 6.6 fabric was placed in acetic acid solution and substrate dyes. The Erlenmeyers were placed on the stove and the dyeing was done in different time intervals. The ratio of the bath was 20:1. Processing time with continuous stirring was 5, 10, 20, 30, 40, 50 and 60 minutes. The dye used is Solophenyl green 5BL (Huntsman, USA). The solution in the constant amount contained dye concentrations of 5, 10, 15, 20, 25 and 30 mg/dm^3. The samples were stained at a temperature of 95 °C. Upon completion of staining, the samples were separated and washed with water.

The absorbance at the maximum wavelength was measured for color (680 nm), spectrophotometer (Cary 100 Conc UV-VIS, Varian). The absorbance of the solution was measured for making a calibration curve and determining unknown concentrations during staining.

The degree of dye exhaustion was calculated using the form:

$$\text{The degree of dye exhaustion} = \frac{C_0 - C_t}{C_0} \times 100\ (\%) \quad (1)$$

where: C_0 and C_t (mg/dm3) are initial and dye concentration at time t (Tayebi et al., 2015).

The amount of absorbed dye per unit mass of the adsorbent (absorption capacity) was obtained using the equation:

$$q_t = \frac{C_0 - C_t}{w} \times V \quad \text{and} \quad q_e = \frac{C_0 - C_e}{w} \times V \quad (2)$$

where q_t (mg/g), is mass of absorbed dye per unit mass at dye time t; q_e (mg/g), is mass of absorbed dye per unit mass in equilibrium, C_0 (mg/dm^3), is initial dye concentration; C_t (mg/dm^3),is dye concentration in solution at dye time t, C_e (mg/dm3), is equilibrium dye concentration in solution; w (g), is mass of sample and V (dm^3), is volume of staining solution (Tayebi et al., 2015).

Results and Discussion

The ability to dye polyamide 6.6 fabric with substrate dye implies knowledge of the existing dyeing mechanisms with conventional dyes, as well as creating assumptions as it would be with a new dye of a different structure. It is known that polyamide fiber usually has an average molecular weight of 10,000-12,000, and at its ends can contain an equal number of carboxyl and amino groups. In practice, it often contains free carboxyl groups and a small number of free amino groups. The presence of these end groups is of great importance and influence on the dyeing of polyamide fibers (Tayebi et al., 2015).

When considering the mechanism of dyeing polyamides with acid dyes that show a greater or lesser affinity for the fiber, it indicates that the adsorption of acid dyes for the fiber can take place in three ways depending on the nature of the dye and the pH of the dye solution. Having in mind the active sites where the dye is adsorbed, the binding of the dye can be organized in the following ways: binding to amino groups, binding to amide groups and binding to positively charged amide groups. Binding of the dye by establishing hydrogen bridges between the corresponding groups of the polyamide chain and the dye molecules is also possible in solutions at pH 2-7, but for groups of dyes showing high affinity for polyamide in neutral solutions (Tayebi et al., 2015).

The diagram in Figure 1 shows the influence of time or length of contact between the adsorbate (dye) and the adsorbent (polyamide 6.6 fabric) on the adsorption-depletion of dye during dyeing, for different initial concentrations of substrate dye. Continuity in changes over time is noticeable. At all initial concentrations, in the beginning, there is a sharp increase in color depletion, and after 30 minutes of staining, this trend is much milder by the end of staining. The linear parts of the curve reflect the diffusion in the surface layer while the parts of the plateau on the curve correspond to the diffusion in the pores.

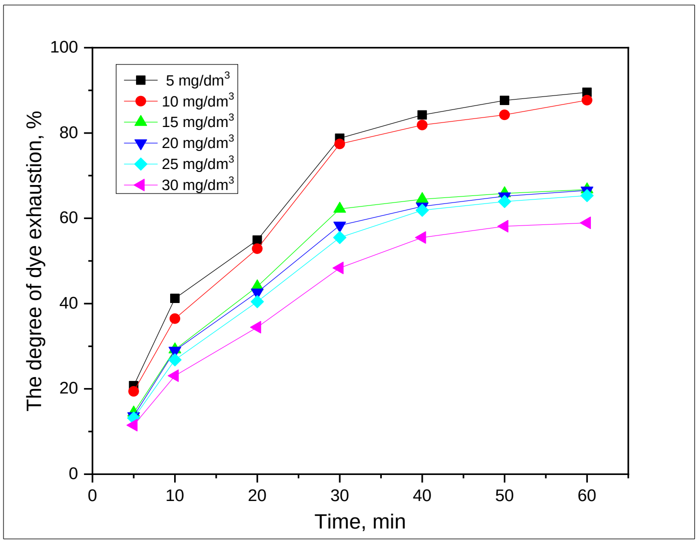

Figure 1. Change in the degree of dye exhaustion of direct dye during dyeing of polyamide 6.6 fabric for different initial dye concentrations

The influence of the initial dye concentration on the adsorption - dye depletion during standard dyeing of polyamide fabric, for different times, is given by the diagram in Figure 2. There is continuity in the changes during the growth of the initial dye concentration. As the concentration increases, the degree of color depletion decreases depending on the adsorption-staining time. At lower concentrations of paint in the solution, at the beginning there is a slightly larger drop in the percentage of exhausted paint, and at the end of painting this drop was somewhat milder. The shortest staining time (5 min.) causes the lowest depletion values, while the longest staining time (60 min.) Produces the highest depletion values.

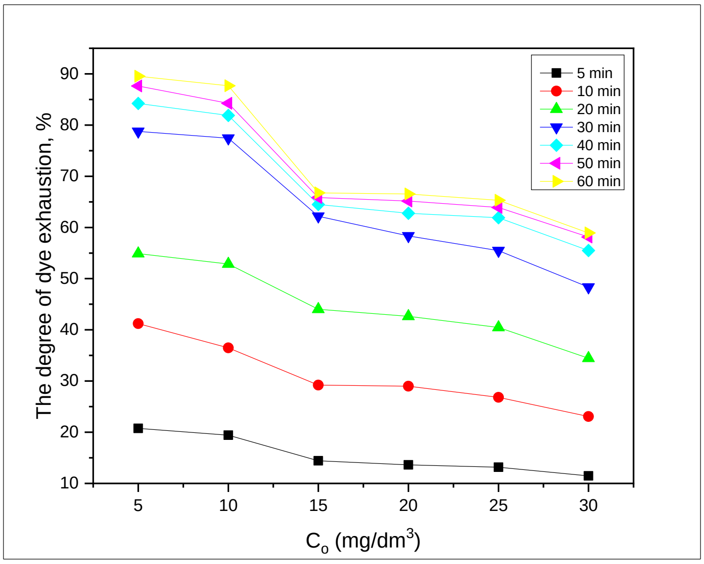

Figure 2. Influence of the initial dye concentration of direct dye on the degree of exhaustion dye

The diagram in Figure 3 shows the results of the change in the adsorbed amount of adsorbate (dye) on the adsorbent (PA 6.6 fabric) for different initial concentrations and dyeing time. With an increase in the initial dye concentration, the dye absorption on the polyamide 6.6 fabric increases sharply, especially after 10 minutes of dyeing up to 60 minutes, where the curve is the steepest.

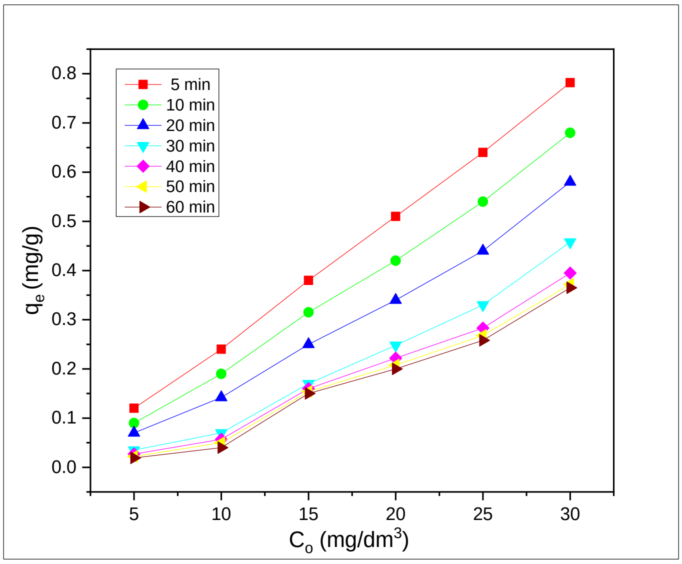

Figure 3. Adsorbed amount of direct dye per unit mass of PA 6.6 fabric in relation to the initial dye concentration for different time of dyeing

Figure 4 is a diagram showing the adsorbed amount of direct dye per unit mass of PA 6.6 fabric over time for different initial dye concentrations. As the initial dye concentration increases, the dye absorption on the polyamide 6.6 fabric increases over time, especially after 30 minutes of dyeing up to 60 minutes, where the curve is the steepest.

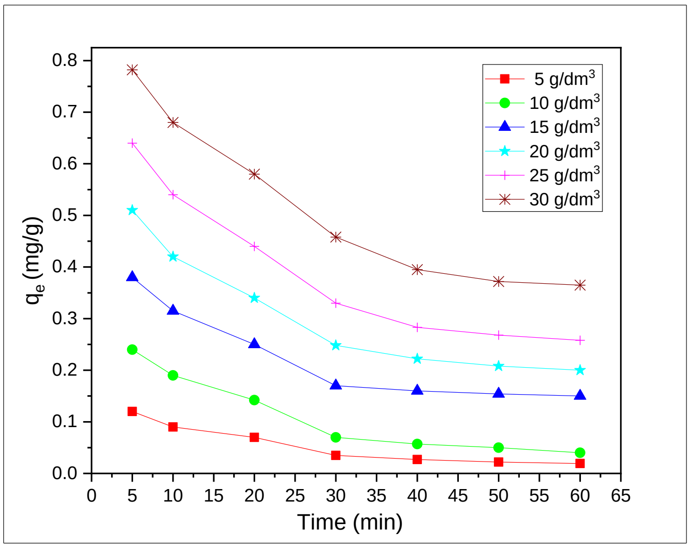

Figure 4. Adsorbed amount of direct dye per unit mass of PA 6.6 fabric in relation to time for different initial dye concentrations

Conclusion

According to the results of experiments and statistical data, dyeing of PA 6.6 fabric can also be achieved in industrial conditions, which of course requires adapting the recipes to the new space and equipment. Based on the obtained experimental results, it can be concluded: Dyeing PA 6.6 fabric with substrate dye in laboratory conditions gives excellent results at a temperature of 95 °C.

Increasing the concentration of dye when dyeing PA 6.6 fabric with substrate dye reduces the degree of depletion, longer dyeing gives a higher degree of dye depletion, and this is maintained throughout the dyeing process. The change in the adsorbed amount of adsorbate (dye) on the adsorbent (fabric), for different initial concentrations and dyeing time, increases during the increase of the initial concentration and time, ie. a greater amount of dye or a longer period of dyeing yields a greater amount of adsorbed dye per unit mass of fabric.

References

Džokić, D. (1989). *Teorija i tehnologija bojenja tekstilnog materijala*, Beograd, Zavod za grafičku tehniku – TMF.

Liu, X., Wang, W. & Xu P. (2010) Improving the Wash Fastness of Direct Dyes on Cotton by Si/Ti Composite Nanosol. *Fibres & Textiles in Eastern Europe*, *18,* 93-96.

Novaković, M. (1996). *Teorija i tehnologija oplemenjivanja tekstila bojenjem i štampanjem*, Beograd, BMG.

Parvinzadeh, M. (2012). Surface modification of synthetic fibers to improve performance: recent approaches. *Global J Phys Chem*, *3*, 1-11.

Rietzler, B., Bechtold, T., & Pham, T. (2018). Controlled surface modification of polyamide 6.6 fibres using $CaCl_2/H_2O/EtOH$ solutions. *Polymers*, *10*, 207.

Tayebi, H. A., Yazdanshenas, M. E., Rashidi, A., Khajavi, R., & Montazer, M. (2015). The Isotherms, Kinetics, and Thermodynamics of Acid Dye on Nylon 6 with Different Amounts of Titania and Fiber Cross Sectional Shape. *Journal of Engineered Fibers and Fabrics*, *10,* 97-108.

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