DYEING OF POLYESTER

Aims:

1. To dye polyester fabric with a disperse dye.
2. To determine which fibers in a multi-fibre strip are dyeable with disperse dyes
3. To observe the influence of a carrier on the disperse dyeing of polyester.
4. To observe the influence of heat setting on the disperse dyeing of polyester.

Theory:

Synthetic fibres are prepared from man-made polymers by extrusion through spinnerets, either from the molten state or from a solution in an organic solvent. They differ from natural fibers and rayon in moisture regain and difficulty of dyeing. Nylon can be conveniently dyed with water-soluble acid dyes. Polyester exhibits a lower regain (0.4% vs. 4% for nylon) and does not possess a terminal functional group to which an ionic dye is attracted. However, polyester can be dyed by disperse dyes, these are non-ionic dyes with finite, but very limited water solubility. This class of dyes obtained its name from their application conditions, as they are applied as a very fine dispersion or suspension in water.

Four methods have been used for dyeing polyester fabrics:

a. conventional aqueous dyeing (batch dyeing)
b. aqueous dyeing with a carrier (batch dyeing)
c. high-temperature (above 100°C usually 130°C) aqueous dyeing (batch dyeing)
d. "Thermosol" dyeing (continuous dyeing)

When dyeing polyester with disperse dyes at 100°C without special auxiliaries known as carriers only light shades can be obtained, this is because of the low dye absorption rate by this method, other techniques are required to obtain medium or heavy shades.

A carrier is an organic chemical that has an affinity for and will swell polyester fibres, chemicals such as biphenyl, orthophenylphenol, benzyl benzoate, butyl benzoate, 1,2,4-trichlorobenzene and butyl phthalamide have been used. The use of a carrier at 100°C increases the amount of dye absorbed AND decreases staining of other fibers by disperse dyes. Dyeing at 130°C without carrier causes an even greater increase in dye absorption and promotes leveling. Carriers normally have an unpleasant odour that requires the dyebath to be enclosed. They may also be toxic.

Another advantage of dyeing at elevated temperatures or with a carrier is increased penetration into the fibre. This is important because with disperse dyes on polyester, complete penetration results in better fastness to washing, rubbing, and sublimation than with similar but un-penetrated dyeings.

"High temperature" usually refers to temperatures greater than 100°C. In commercial dyeings, it refers specifically to 130°C. Aqueous high temperature dyeing with disperse dyes is more economical than aqueous dyeing with carrier. Dyeing at high temperature eliminates the need for a carrier to "carry" the dye into the fibres.

The **Thermasol Process** consists of padding disperse dyes on to the fabric, drying the fabric, and heating to 195°- 210°C to drive the dyes (thermasol) into the fibers that have been swollen by the elevated temperatures. This process can be modified to continuously dye cotton/polyester blends by inclusion of a dye for cotton (vat, sulfur, or fiber reactive) in the pad bath. After thermasoling, the fabric is then treated in a manner that will fix the cotton dye.

Ortho Phenylphenol (OPP) is an effective carrier for applying disperse dyes to polyester and was one of the most important carriers in use in the early days of polyester dyeing. With the advent of High Temperature dyeing carrier dyeing has almost completely been replaced and many of the older type carriers have been replaced with less toxic more environmentally friendly products. Butyl benzoate and Butyl phthalamide are now widely used as carriers particularly for the dyeing of polyester wool and polyester nylon blends. Butyl phthalamide is available from Yorkshire Chemicals as a free flowing self-emulsifiable liquid. Carriers may also be used to increase the migration of very high energy disperse dyes and to repair unlevel batches of fabric.

Carrier concentration in the bath is important. Sufficient carrier is required to promote dye penetration into the fibers. Excess carrier must be avoided as it may introduce a third phase (in addition to the dye and the water) that will compete with the fibres for the dye and thus reduce the yield of the final dyeing.

It is important that as much carrier as possible be removed from the yarn or fabric after dyeing because fastness properties, particularly light fastness, can be reduced by traces of some carriers. Another reason for complete removal of carriers from dyed fabrics is to prevent skin irritations in wearers who might be sensitive to these chemicals. To effect complete removal of residual carrier and loose surface dye, carrier-dyed fabrics are normally given a reduction clear using sodium hydrosulphite and caustic soda at 60°C for 10 – 15 minutes. Sodium hydrosulphite is a reducing agent that destroys the surface deposited dyestuff that if not removed would result in dyeings of poor fastness to wet treatments as well as rubbing. High temperature dyed fabrics and yarns are also given reduction clear to remove any surface deposited dyestuff.

When synthetic fibres are generated and converted into fabrics, stresses from these manufacturing processes will be stored within the internal structure of the fibres. If these stresses are not relieved, the fabrics will shrink during normal heating drying cycles during use. To minimize this in-use shrinkage, polyester fabrics are usually heat-set at a temperature of 195° - 210°C for 30-90 seconds in a stenter. The energy provided by this heating allows the polymer molecules to move more freely in the fibre, promoting relaxation of manufacturing-induced stresses. When the fibres cool, the fibres are relaxed and will maintain their length unless the heat-setting temperature is exceeded. Heating above the heat-setting temperature may cause shrinkage.

Heat-setting thermoplastic fibres helps the polymer molecules settle into conformations where they are closer together. Intermolecular attractive forces are increased. This may decrease both the rate of dyeing and the amount of dye that can be exhausted to the fabric. If this is a problem, heat-setting may be done after the fabric has been dyed: Heat setting after dyeing may produce two other problems. Some disperse dyes may sublime during heat-setting, causing a change in shade. In addition, heat-setting usually stiffens the fabric. When heat-setting precedes dyeing, this stiffness is removed by the mechanical action exerted on the fabric during dyeing. Both sequences are practiced.

Equipment and Chemicals

- Polyester fabric approximately 2x 5 gm. one piece will have been heat set at 210°C for 60 seconds multi-fibre fabric
- C. I. Disperse Red 92 (1.0% solution Serilene Red TBLS Yorkshire Chemicals)
- 10% solution of Dyapol ABA a buffered dispersing agent.
- 10% emulsion of Optinol BTH carrier (Yorkshire Chemicals)

CAUTION -WEAR SAFETY GLASSES AT ALL TIMES DURING THIS PRACTICAL

Experimental Procedure No.1

Attach the multi-fibre strip to the unset piece of fabric with two staples.

1. Prepare the dye bath at 60°C at a liquor ratio of 30:1 as follows;
   - 1.0g/l Dyapol ABA
   - 5.0g/l Optinol BTH
   - Add the wetted out fabric and circulate for 5 minutes.
   - Add 1.0% Serilene Red TBLS o.w.f.
   - Circulate 4-5 minutes at 60 °C
   - Then raise temperature to the boil over 15minutes (approx. 2.0°C per minute)
   - Dye at the boil for 40 minutes. Add small amounts of hot water to the dyebath to maintain a constant liquor ratio.
2. At the completion of the dyeing rinse well in warm water and then,
3. Reduction Clear:
   - 2g/l Sodium Hydrosulphite
   - 2g/l Sodium Hydroxide (caustic soda)
   - 10 minutes at 60 °C
4. Rinse well in cold water and neutralize:
   - 1g/l Acetic Acid
   - 5 minutes at 40°C
5. Dry the dyeings in the drying cabinet and compare the set and unset samples. Evaluate the staining of the multi-fibre fabric using the grey scales.

Experimental Procedure No.2

High temperature dyeing

1. Fasten the fabric around the carrier so that all the holes are covered.

2. Enter the carrier into the dyebath and fill the bath with 500ml of water using the automatic filling arrangement;
    - Press **No.1 Fill** set the volume of liquor and press **enter**,
    - Press start to activate the fill.
    - When filling is complete set the flow by pressing **no.6** on the menu, set the flow to 100%.
    - Press enter, and then start.

3. Set the temperature **no.7** to 60°C rate of rise 5.0°C per minute and press start.

4. Add 1g/l Dyapol ABA and circulate while the temperature raises to 60 °C.

5. Add 1% Serilene Red TBLS.

6. Seal down the lid, then reset the temperature to 130°C with a rate of rise of 2.5°C per minute. Check the time it will take for the machine to reach 130°C.

7. Dye at 130°C for 30 minutes.

8. At the completion of 30 minutes. **DO NOT OPEN THE CHAMBER.**

9. Reset the temperature to 75°C and 5.0°C per minute to cool the vessel.

10. When temperature reaches 75°C, drain the vessel using the drain instruction on the computer.

11. Open the chamber only after pressure reads zero.

12. Refill with cold water and set temperature to 60°C & 5.0°C rate of rise.

13. Open the chamber and add
    2g/l Sodium Hydrosulphite
    2g/l Caustic soda

14. Raise temperature to 60°C and treat for 5 minutes.

15. Drain, rinse and neutralize with 1g/l Acetic acid.

16. Rinse cold, remove dyeings and dry.

17. Compare the dyeings at high temperature against those using carrier and comment on the reasons for the difference.

Questions.

1. What effect has heat setting of the fabric on the dye uptake?
2. What effect has H.T. dyeing on the uptake of the heatset and un-heatset fabric compared to the carrier dyeing process?
3. Why are the dyeings reduction cleared and what would be the effect if no reduction clearing was used?

References

1. Giles, C. H., A Laboratory Course in Dyeing, 2nd Ed., 1971.
2. Trotman, E. R., Dyeing and Chemical Technology of Textile Fibers, fourth edition, 1970.
3. Arthur D. Broadbent, The Basic Principles of Textile Coloration. Society of Dyers & Colourists, 2001