Migrate to a Better Situation

A Solution to Thermomigration

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Today, synthetic fibres occupy a prominent position in the multifibre industry. The large-scale introduction of these fibres in the textile industry has created a number of problems for the dye manufacturer, textile dyer and finisher, as they require special dyes, chemicals and techniques for their chemical processing.

The world production of synthetic fibres has increased at a very rapid rate during the last 50 years. As far as individual synthetic fibres are concerned, polyester fibre fully dominates the market with approximately 75% of total production of synthetic fibre. Among the various fabrics used today in apparel, polyester fabrics dominate in markets, due to their properties such as durability, dimensional stability, fashionable look, cheaper price, brighter shades, etc.

Polyester fibre became the most important synthetic fibre over the past half century and reached the status of the highest volume of production among the other synthetic fibres. Disperse dyes, being the most suitable dye class for polyester fibres, also became one of the highly consumed dyes.

Whenever the word 'migration' comes up, no matter what the context, the experienced dyer always thinks of migration during intermediate drying, although this word has, over the years, been used for a number of very different processes.

Thus in the sixties, the word 'migration' was used for the levelling of dyes in the exhaust process. The word 'migration' was also used in an explanation of dye transfer in the thermosol dyeing process. Finally, we also talk of the migration of dye from the outside to the inside of a fibre. And the term 'thermomigration' has also existed for a number of years. 'Migration' in general terms means the movement of dye in or on a textile fibre under certain treatment conditions.

Thus migration processes play a part in:

- Levelling in exhaust dyeing – called **Levelling**
- Drying of padded textiles – called **Migration**
- The movement of dye from the surface to the core of a fibre – called **Diffusion**
- The movement of dye from the inside to the outside of a fibre when dyed textiles come in contact with certain auxiliaries – no temperature effect – called **Solvent bleeding** or **Desorption**
- The movement of the dye from the inside to the outside of fibres when the dyed textiles come in contact with finishing agents and softeners during curing, and in drying and heat-fixation processes generally – called **Thermomigration**

The term '**thermomigration**' of dyes is currently used to describe the phenomenon in which the movement of disperse dyes out of synthetic fibres or their blends during application of different finishes at high temperatures or during storage takes place. Such dye migration results in change in shade, water-spotting, inferior fastness of dyed and finished fabrics, mark-off of prints and staining on adjacent garments made from synthetic fabrics during simultaneous washing in washing machines.

In addition, sometimes 'thermomigration' is attributed to the dissolution of the colour in the finishing agent and due to its consequent mobility; migration is caused by the possible existence of a temperature difference on either face of the fabric and/or across the width during curing at higher temperatures. Non-ionic finishes possess greater propensity to cause such problems. It is desirable to completely fix the colour, as unfixed colour will be more vulnerable to the phenomenon discussed above.

Thermomigration and its Effect on Wet Fastness of Disperse Dye

Polyester does not contain any groups that can be used to fix a dye, either by reaction or by attractive processes, hence the dye is merely held in solid solution. It follows that a dye that is readily taken up by the fibre is equally ready to come out, so that thermal migration and poor fastness, leading to cross-staining, have posed serious problems in polyester colouration.

The fastness properties of polyester and polyester blends dyed with disperse dyes are impaired by heat treatment, finishing chemicals or a combination of both. The complex problems surrounding this subject are often loosely summed up by the term 'thermomigration'. This can drastically alter the crocking and wet fastness of dyeings that were previously of excellent standard.

In recent years, the problem has gained new significance such that, on the one hand, fashion called for garments with extreme, fashionable colour contrasts, yet on the other hand, the fastness requirements for the same garments were considerably increased owing to tighter test specifications – not always, by the way, for the good of the consumer, but often only to gain an advantage over the competition.

Even though the unfixed dye can be completely removed from the fibre surface by a thorough reduction-clearing treatment, problems may occur with subsequent finishing treatments. The large amount of dye needed for microfibres results in greater migration to the fibre surface by thermomigration than occurs with the conventional polyester, leading to lower wet fastness.

Factors that Influence Thermomigration

- *Effect of Substrate*
  In the case of polyester microfibre, the surface area available to absorb the dyestuffs is far greater than in normal fibre, which results in increased dye pick-up, because the dye has to penetrate into the surface of more filaments. However, the amount of dyestuff required for microfibres may be 2-3 times as high as for normal fibres to achieve the same shade. Therefore, the possibility of thermomigration is more in disperse-dyed microfibres than in normal polyester after the finishing process.

- *Effect of Fibre Blend Ratio*
  With fibre blends having more than a 50% polyester component, desorption or thermomigration processes are important. The fabric with the greater proportion of polyester has lower fastness properties, because the absolute amount of desorbed or thermomigrated dyestuff per unit area or weight is greater in these fabrics, owing to the higher quota of polyester.

- *Effect of Coning Oils*
  The non-ionic emulsifiers contained in finishing products are very good solvents for disperse dyes. They can cause a deterioration in rubbing fastness. The extent of dye desorption depends both on the dye concentration in the fibre before heat treatment and on the chemistry of the finishing agent, as well as time and temperature. It has now been ascertained that thermomigration also occurs with ionic surfactants.

- *Effect of Amount of Dye on The Fibre*
  The deeper a dyeing is, the more the disperse dye can thermomigrate per unit area and stain the adjacent multifibre tape in the subsequent wet-fastness test.

- *The Characteristics of Dye*
  Although desorption and thermomigration are dye-specific properties, it might happen that a dyeing produced with easily subliming disperse dyes will behave worse with regard to thermomigration than one produced with sublimation-fast dyes. However, the less sublimation-fast dye is even better at producing thermomigration-fast dyeings. The tendency of a disperse dye towards desorption and/or thermomigration can thus be considered to be a characteristic of dyestuff which does not depend on the sublimation fastness.

- *Dyeing and After-cleaning Conditions*
  In many cases, thermosol dyeings show less thermomigration than HT dyeings, with carrier dyeing being the worst in this respect. These differences are clearly due to variation in the penetration of the dye into the polyester fibres.

- *Effect of Finishing Agents*
  It has already been mentioned that the finishing agents and their application conditions have a decisive influence on the fastness properties that can be expected. Softener, polysiloxane emulsions, resin and antistatic agents have extractive action on disperse dyes during curing and as well as during storage. This can also lead to deterioration in fastness properties as a result of the thermomigration of disperse dyes.

- It is observed that synthetic-resin components containing –OH or –OCH3 substituents have greater deterioration effect on fastness than the non-substituted product. Textile containing a certain amount of surfactant that has not been adequately washed out causes deterioration of colour fastness.
- The dyestuff migration that occurs is dependent upon the duration of storage, the surfactant-chain length and the iogenicity. Dyestuff migration is less in the presence of anionic surfactant. Non-ionic and cationic products cause greater migration of the dyestuff, and the differences between dyestuffs may also occur in this case. After heat treatment the amount of dyestuff that has diffused out is to be found in the surfactant. From here, it can be washed out with water or with organic solvents.
- The amount of dyestuffs that can be washed out is directly related to colour fastness and to its deterioration. Therefore the finisher will first and foremost ask himself under what conditions of heat the adsorption phenomena will impair fastness, or to what extent this problem can be minimised by controlling the conditions of time and temperature during final finishing.

Remedial Actions to Improve Fastness Properties

Knowledge of the manifold causes and circumstances that lead to problems with fastness properties provides the necessary foundation for a discussion on all measures that can be taken to tackle the problem.

If one is confronted with such a situation, it is advisable to carry out a careful analysis of the entire manufacturing process of the individual article. Generally speaking, the main thing is to determine for each of the production factors, as listed at the outset, how far they influence the resulting fastness properties. In essence, it must be determined how and to what extent the individual stages of production increase the amount of desorbed or thermomigrated dye that affects the fastness properties.

The following are the areas that can be conclusive in achieving optimum results. In this context, it should be mentioned that the dyer/finisher plays a decisive role in meeting the stringent quality demands, which cannot be influenced as such, and he should reassess his basic processing methods in an endeavour to find optimum solutions.

Choice of Dyestuff

Nowadays the finisher is confronted with the additional task of taking into account the 'thermomigrational behaviour' of disperse dyes, in addition to their dyeing properties, fastness properties and economics. The right choice of dyestuff is the most obvious issue, and addressing it is one of the most effective steps that the finisher can take when confronted with problems of fastness properties. In order to limit, as far as possible, the fastness problems caused by thermomigration, the following properties are desirable:

- Well-penetrated dyeings in a short dyeing time and at a low dyeing temperature
- High sublimation fastness
- Little staining of cotton in the HT and thermosol dyeing of polyester/cellulose blends
- High dispersion stability
- Easy reductive decomposition to colourless products of the lighter shades
- Low solubility in the usual finishing products
- Low tendency to dye polyester or polyamide from washing liquor

It is not possible, unfortunately, to combine all these requirements in one dye. It is always necessary to seek a compromise.

Choice of Chemicals

The degree of thermomigration depends on the type of dyes, the additionally applied finishing chemicals and the type of fastness test. A large proportion of fastness problems are caused by disperse dyestuffs in the presence of finishing chemicals such as softener, where finishing agents form a thin film around the fibres, which acts as a dissolving medium for the disperse dye that migrates from the inner surface to the outer surface of the fibre during hot-air fixation and/or curing. So it seems logical to use the right finishing chemical to minimise the thermomigration. With a well contemplated choice of chemicals and dyes, however, significant improvements in fastness properties can be achieved.

In order to minimize the thermomigration caused by normal softening agents after the finishing stage, Sarex has developed a softener, Hydrosoft NTM, which shows negligible thermomigration, resulting in better fastness properties as compared to competitive softeners.

Materials and Experimental Methods

For experimental study, after the dyeing process, polyester fabrics were subjected to reduction clearing to remove the unfixed dye from the fibre surface. After

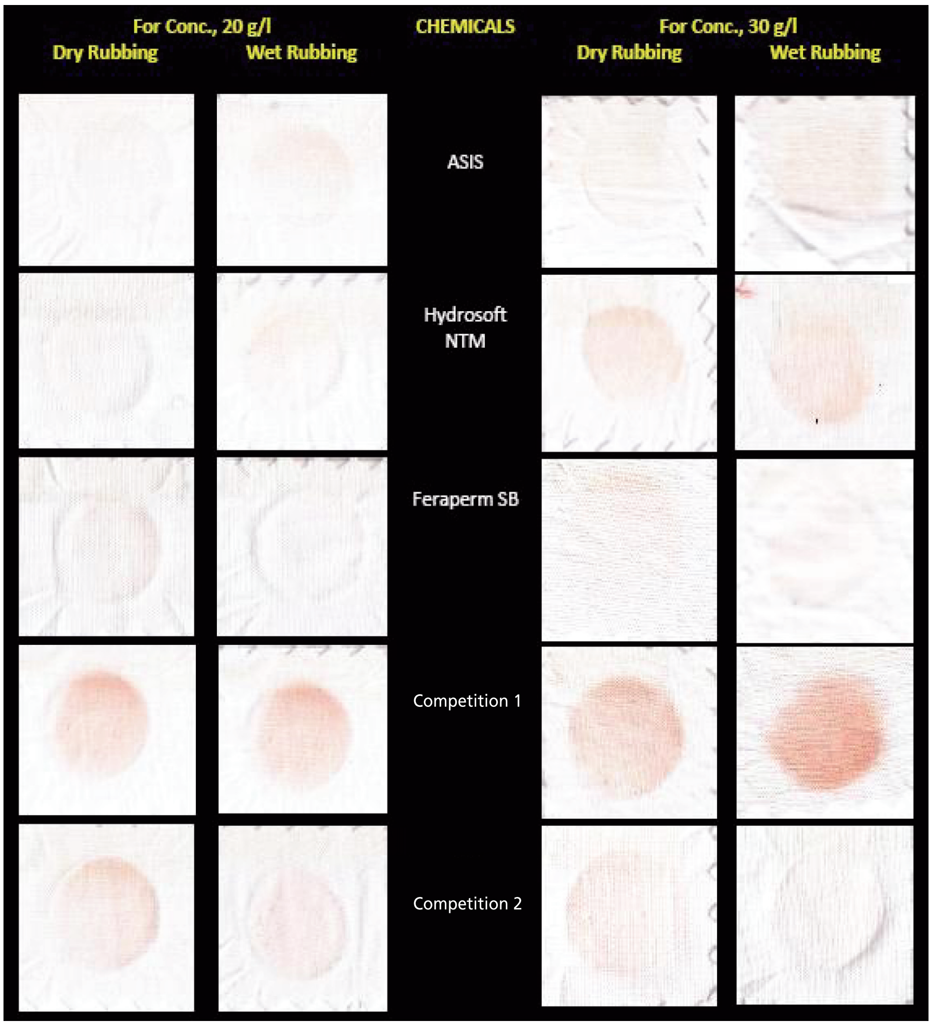

Figure 1: Transfer of colour from finished substrates during rubbing-fastness test

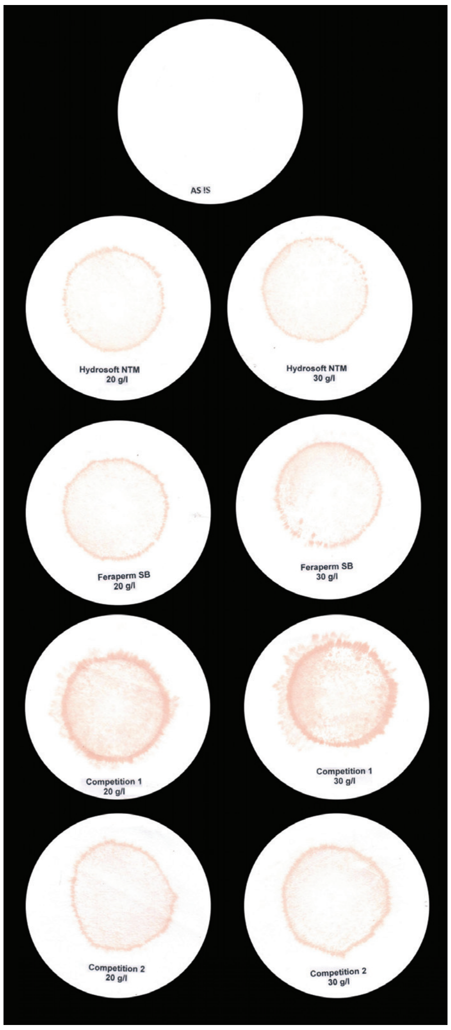

Figure 2: Chromatographic test of finished substrates

reduction clearing, detailed study of thermomigration was carried out with various finishing agents on polyester dyed with Brown 1 dye. Finishing was carried out by pad application for 20 g/l and 30 g/l concentrations, at pH 5-6 for 65-70%. After padding, drying was carried out at 180°C for 1 minute. After finishing, the finished substrates were evaluated for the extent of thermomigration by the Nike method and chromatographic test method. Also, fastness properties were evaluated in terms of dry and wet rubbing fastness.

Evaluation of Finishing Agent

Dye Migration by Nike Method
Preconditioned test specimens (ISO 139, using Standard Temperature Atmosphere) were subjected for standard test Nike test, in a preconditioned oven at a temperature of 90°C ± 5°C (194°F ± 9°F) for 24 hours. The adjacent white test specimens were then evaluated using a spectrophotometer for the extent of staining on the white fabric.

Colour Fastness to Rubbing
Colour fastness to rubbing was tested by ISO 105 PART X12 to check the rubbing-off and staining of dye on other materials. Testing was carried out for both dry and wet rubbing fastness using a Crockmeter.

Chromatographic Test
In this method, 4.5cm round fabric was kept on the Whatman filter paper No.2 and sandwiched between two glass plates. Then 0.5ml tetrachloroethylene was added through the centre hole of the glass plate. The Whatman filter paper was allowed to dry and the spreading of colour was observed visually.

Results and Discussion

The evaluation of thermomigration was carried out by the Nike method, rubbing fastness and chromatographic test and results are expressed in Table 1 and Figures 1 and 2.

From the results it is clear that substrate finished with a 20 g/l and 30 g/l concentration of Hydrosoft NTM and Feraperm SB shows less migration of dye towards the surface when subjected to the Nike test. The trend remained the same for both the finishing agents, which were cured at 150°C and 180°C temperatures.

The samples finished with Competition 1 and Competition 2 agents showed slightly higher thermomigration towards the surface during the test.

The extent of migration of dye at different curing temperatures due to finishes was evaluated by the rubbing-fastness test. Fastness ratings in terms of dry and wet rubbing, expressed in Table 1 and Figure 1, clearly show the thermomigration behaviour of different finishing agents evaluated by the Nike method.

From the results it is crystal clear that the fabric finished with Hydrosoft NTM and Feraperm SB, for 20 g/l and 30g/l concentration, shows a superior rubbing-fastness rating, ie. less thermomigration of dye than with fabric finished with Competition 1 and Competition 2 agents when cured at 150°C and 180°C temperatures.

Also, a chromatographic test carried out using tetrachloroethylene on a Whatman filter showed a smaller amount of dye, with even spreading, for fabric finished with Hydrosoft NTM and Feraperm SB. This indicates less thermomigrated dye on the fabric surface.

Conclusion

Often, a pleasant, soft fabric handle is the decisive criterion in purchasing a textile article and therefore is often regarded as the most important factor for saleability. Softeners are of great importance in textile processing, and these days almost every single textile piece leaving a textile mill is treated with softener – hence products such as softeners, crosslinkers and filling and stiffening agents make up the largest categories within the range of textile auxiliaries. But looking at the problem of thermomigration due to softeners available in the market, use of our products such as Hyrosoft NTM and Feraperm SB can give some relief to textile finishers. ID

Table 1: Strength of thermomigrated colour and rubbing fastness of fabric finished with different softeners

Products	% Strength				Rubbing fastness							
	For 20g/l		For 30g/l		For 20g/l				For 30g/l			
	150°C	180°C	150°C	180°C	150°C				180°C			
					Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
As is (STD)	100	100	100	100	5	4	5	4	5	4	5	4
Feraperm SB	111	111	123	103	3-4	3-4	5	4	3-4	3-4	4	4
Hydrosoft NTM	100	108	132	111	3-4	4	4-5	4-5	4	4	3-4	3-4
Competition 1	133	161	191	160	2-3	2	3-4	3	3	2	3	2
Competition 2	99	122	132	128	4	4	4	4	4	4	3-4	4