NEW DEVELOPMENTS IN CONTINUOUS DYEING OF PES/CELLULOSIC BLENDS

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Rising cost pressure remains a major issue in the textile industry and especially textile finishing. Reasons include the steadily rising cost of energy, water and effluent treatment.

Dyeing of polyester/cellulosic wovens and knitgoods is typical of where the problems are encountered. The established methods of dyeing such blends are extremely time and cost-intensive. They require large amounts of water and chemicals and use a good deal of energy.

This paper focuses on continuous dyeing of such blends with reactive and disperse dyes. As well as outlining the problem, it presents an alternative method which is of interest on both ecological and economic grounds.

Fibre and dye-specific properties

To understand why so much effort is spent on dyeing PES/cellullosic blends despite the problematic cost situation, it is worthwhile looking at some fibre and dye-specific aspects.

Reactive dyes, cotton	Disperse dyes, PES
Alkali required to fix the dye	Sensitive to alkali
pH 10.8-13.5	pH 4-6
Sensitive to reduction	Reductive clearing is necessary to optimise fastness properties
Fixation of damp goods	Fixation of dry goods …
Cotton yellows at elevated temperatures	… at 200 -220 °C

<u>pH</u>

Reactive dyeings have to be fixed in an alkaline medium Usually soda ash alone or in combination with caustic soda are used to set the pH at 10.8-13.5. This greatly reduces the yield of common disperse dyes (Fig. 1).

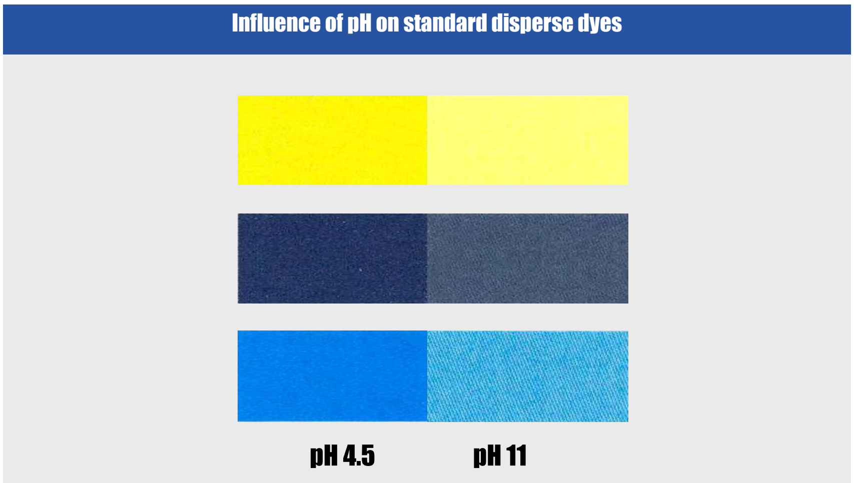

Fig. 1

Sensitivity to reduction

Some reactive dyes are extremely sensitive to reducing agents. This sensitivity is found at all steps in the process, especially after application of the dyes. Although some disperse dyes are sensitive to reduction during the dyeing phase, reductive clearing is normally carried out after dyeing as it improves the fastness properties of the dyed substrate.

Fixation conditions

Reactive dyes are water-soluble and are therefore fixed to the cellulosic fibre in a moist medium. In conventional continuous dyeing methods, that means fixation in saturated steam.

However, the disperse dyes used for PES are fixed by thermosoling, i.e. at temperatures of around 210-220 °C. Cellulosic fibres have a tendency to discolour in such conditions (Fig. 2).

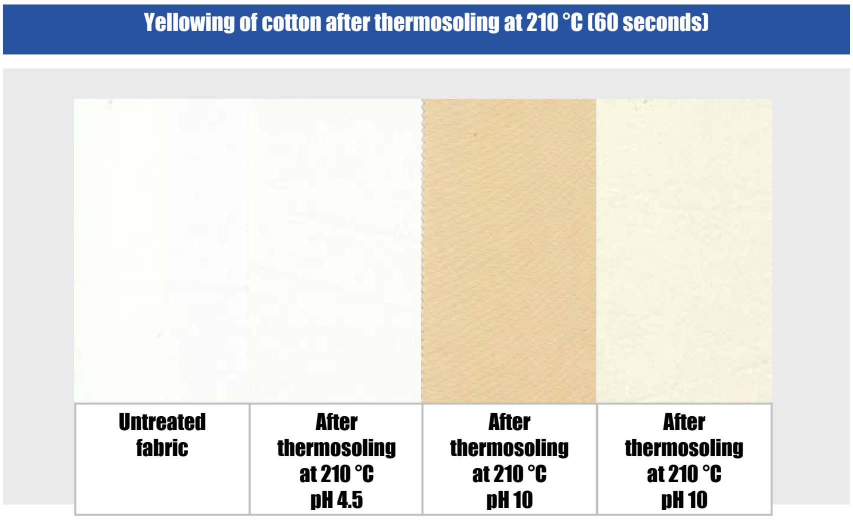

Fig. 2

As a result of these completely different dyeing requirements, multi-step processes using several liquors have been developed for continuous dyeing of PES/cellulosic blends in order to ensure that the optimum conditions are achieved for each fibre. Worldwide, the pad-dry-thermosol-pad-steam process (PDTPS) has become established.

This method is used to dye the cellulosic fibres with either vat or reactive dyes. Vat dyes are popular for all shades in Europe, e.g.. for high-quality workwear.

However, globally the PDTPS process with reactive and disperse dyes is the most common (Fig. 3).

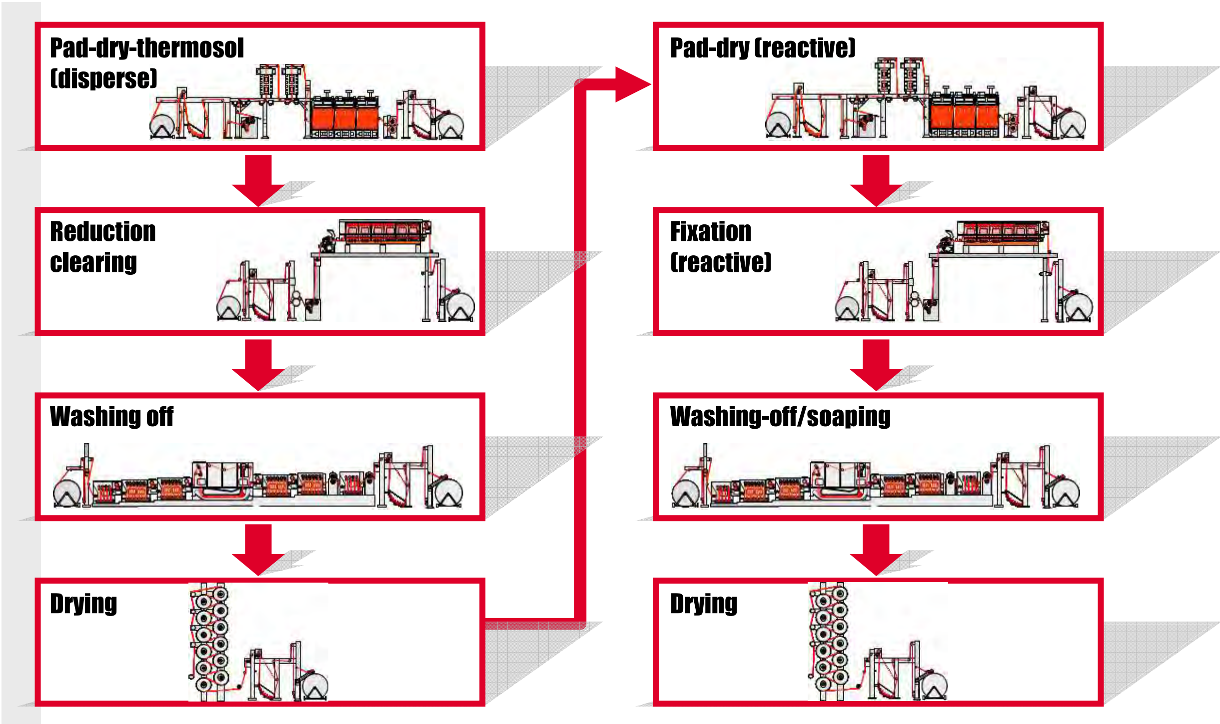

Fig 3. Process scheme PDTPS with reactive/disperse dyes

The steps in the process are outlined in detail below.

1. Application of the disperse dyes
   1a - Drying
   2b - Thermosoling
2. Application of reducing agent
   2a - Steaming
3. Wash-off, neutralisation
4. Drying
5. Application of the reactive dyes
   5a - Drying
6. Application of alkali
   6a - Steaming
7. Washing off, soaping, neutralisation
8. Drying

Chemicals required for the PDTPS process (guide recipes):

1st bath (disperse dyes)
2 g/l dispersing agent
2 g/l wetting agent
10-20 g/l antimigrant

2nd bath (reduction clearing)
30 g/l hydrosulphite
50 ml/l NaOH 50%

3rd bath (reactive dyes)
2 g/l wetting agent
10-20 g/l antimigrant

4th bath (alkali)
20 g/l soda ash
3-10 ml/l NaOH 50%
250-300 g/l salt

5th bath
2 g/l soaping auxiliary

The complexity and unusually high chemical requirements are striking. Both aspects are problematic for textile mills.

The complexity of the process reduces reproducibility both in lab-to-bulk transfer and between batches. It is easy to see that each step in the process contains the potential for errors – both in the lab and in production.

The large number of different process steps also makes high demands on logistics and planning. Reductive clearing is a good example. Unless this step is carried out in a separate steamer/washer, careful cleaning of the machine is necessary to prevent problems in subsequent process steps which are sensitive to reduction.

The high chemical requirements mainly relate to the use of electrolytes, generally common salt or Glauber's salt. These chemicals are needed to minimise bleeding of the unfixed reactive dye into the alkaline bath, which would result in inadequate build-up. However, the use of common salt or Glauber's salt has a number of disadvantages:

- Common salt is frequently used to minimise costs, but the quality available on the market varies considerably. Poor quality salt often contains large amounts of calcium and magnesium salts causing hard water.
- The quality of Glauber's salt tends to be more constant but the amounts required corrode concrete.
- Dissolving the required concentration of 250-300 g/l is time-consuming and labour-intensive.

Production costs are a core aspect of production planning. However, these aspects make the costs very difficult to calculate. The absolute amount of water, chemicals and energy can be measured or calculated. In particular, an objective comparison of different processes is possible. A specially developed DyStar program known as "Abacus" was used to generate the following calculations:

Basic data

Article:	PES/CO
Weight:	315 g per m
Liquor pick-up	60% in dye bath and 70% in chemical bath
Machinery utilisation:	70-90% depending on type of machine
Liquor exchange:	30 minutes
Batch size:	1,200 m
Output per day:	20,000 m

The calculation assumes optimum planning, i.e. production of pale then dark shades, without additional exchange of liquor in the washing unit or intensive intermediate cleaning of the padder or steamer.

Under these conditions, daily output in the PDTPS process requires around 1.5 tonnes chemicals and 280 m^3 water, plus the cost of energy, i.e. electricity, gas and steam, which evidently depends on the energy concept used in the mill.

It is already clear that this an expensive method, which is also prone to human error because of the large number of process steps involved.

The following factors explain why this process is nevertheless very widely used around the world:

- Separate process steps permit the use of a wide range of reactive and disperse dyes
- Apparently low recipe costs
- Reductive clearing means that very brilliant shades can be dyed

However, there is also a long list of potential drawbacks:

- Time-consuming
- Very expensive process in total
- Labour-intensive
- Very high water consumption
- Very high energy requirements
- Very high chemical requirements
- Very high investment costs
- Prone to errors
- High environmental impact

On both ecological and economic grounds, it is therefore advisable to look for alternative processes.

So what alternatives are available?

Alternative 1:

The PDTPS process with Indanthren and disperse dyes (Fig. 4)

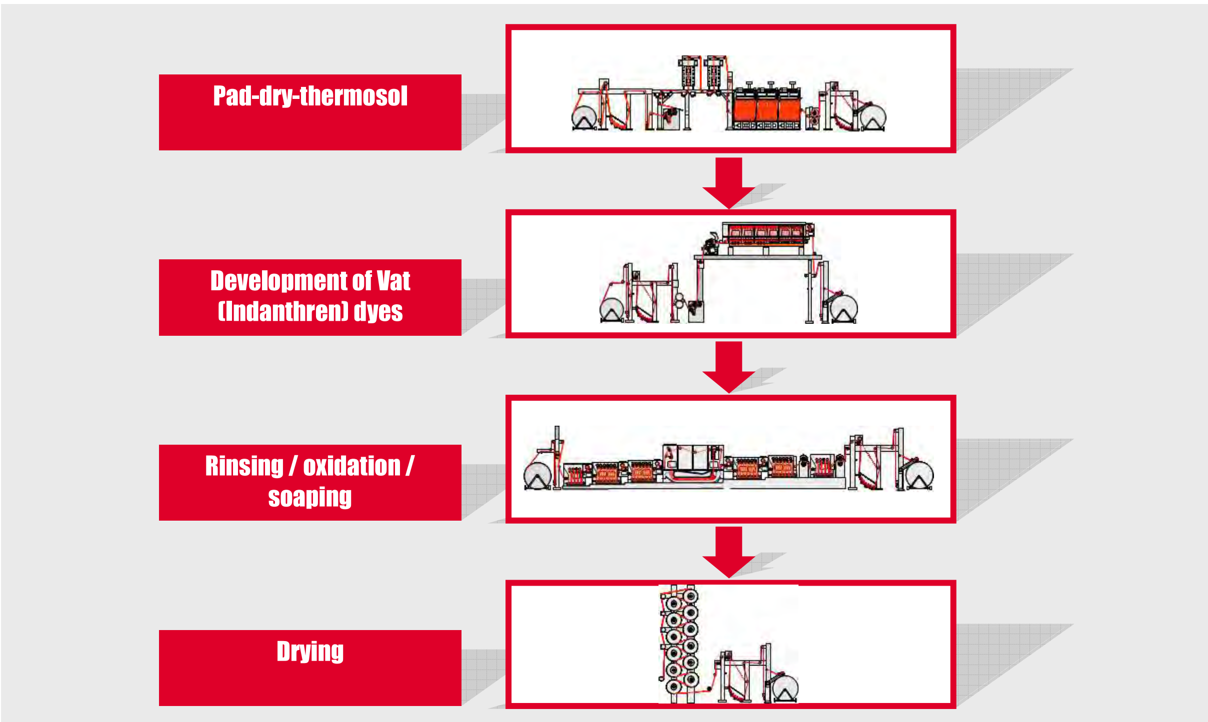

Fig. 4

As the Indanthren dyes are reduced to their leuco form, reductive clearing is not necessary. This saves time, water and energy. Since fastness is extremely high, this is the standard process for high-quality workwear.

The disadvantage is the large quantity of hydrosulphite and caustic soda required. The reduction in water and energy consumption normally has to be set against possibly higher recipe costs compared to dyeings with reactive/disperse dyes.

Alternative 2:

The Compress C Plus process with Caledon SF dyes (Fig. 5)

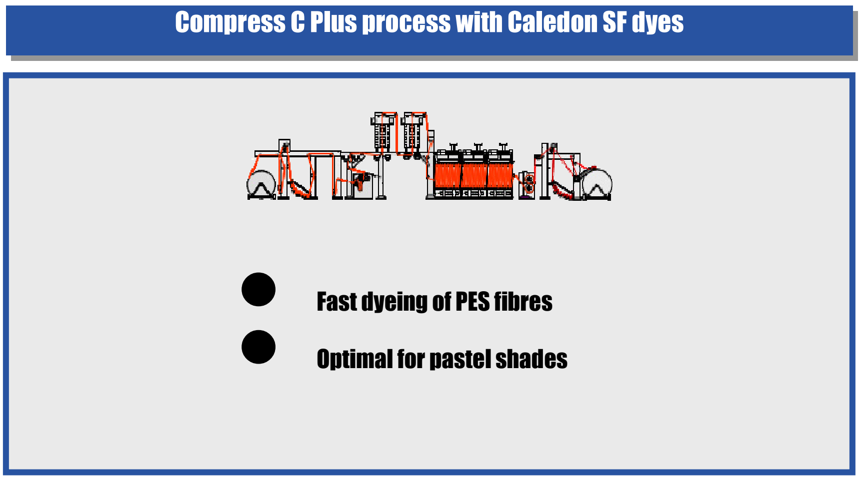

Fig. 5

This process uses specially formulated vat dyes applied with Sera Pad M-PF + Sera Fix C-PV, followed by drying and curing. Washing off is not necessary.

Unlike pigment dyeing, the Compress C Plus process comprises genuine coloration of the PES fibres, giving excellent fastness.

However, build-up is restricted. The optimum application is for pastel shades. In fact, it is the process of choice in this segment as dyeings with high fastness properties are obtained with minimum energy requirements and virtually no water.

One-bath process

Apart from the methods outlined above, there is not yet any real alternative on the market. However, it is clear that the optimum method from the ecological and economic viewpoint is most likely to comprise one-bath application of reactive and disperse dyes.

Since this is so obvious, there have been many attempts in the past to find a suitable one-bath process.

Back in 1967 Kuth/Hildebrand (Bayer AG) described a one-bath thermosol-thermofixation process (TT process) using disperse and reactive dyes.

In 1977 ICI (later Zeneca) published the NT (neutral thermofixation) process based on specially developed Procion T reactive dyes that could be fixed in neutral conditions. This was followed by process recommendations based on dichlorotriazine reactive dyes. Due to their very high reactivity, these dyes (Procion MX) could be fixed with extremely small amounts of alkali. ICI also published the “RTN” process, which used sodium bicarbonate and urea to apply Dispersol and Procion CX dyes (monochlorotriazine reactive groups). Again, this was essentially a conventional thermosol-thermofixation process.

Finally a patent (P 28 09 675.5) submitted by Bayer AG in 1978 described a process for one-bath dyeing of PES/cellulosic fibres in neutral conditions.

The idea behind all these processes was that the thermosol phase could be used to bond the reactive dyes to the cellulosic fibre. However, interaction with auxiliaries such as urea and dispersing agents and the disperse dyes could not be entirely excluded. Besides, they all required the use of dicyandiamide, which is not always available and also has very limited solubility.

In the end, none of these processes became widely established on the market. This may have been partly because water and energy tended to play a less significant role in the overall cost calculation than they do today. However, the main reasons probably related to disadvantages at the production stage, for example, inferior reproducibility, tailing, etc. and limited fastness properties.

As outlined at the start of this paper, the development of a new process and new products therefore needs to focus on the very different requirements of cellulosic and polyester fibres. The objectives are:

- Application of all necessary products from one bath
- No reduction in the degree of fixation of the reactive dye compared with the standard process
- No reduction in the yield of disperse dyes
- No yellowing of cellulosic fibres
- Fastness properties that meet market requirements **without** reductive clearing
- A wide range of shades

This development was assisted by very positive experience with the Econtrol® process developed jointly by Monforts and DyStar, which is widely used very successfully with Levafix and Remazol dyes.

The process for one-bath dyeing of PES/cellulosic blends outlined here is a further development of the Econtrol process.

The underlying principle is very simple (Fig. 6).

- Dye application
- Drying + thermosoling
- Washing-off/drying

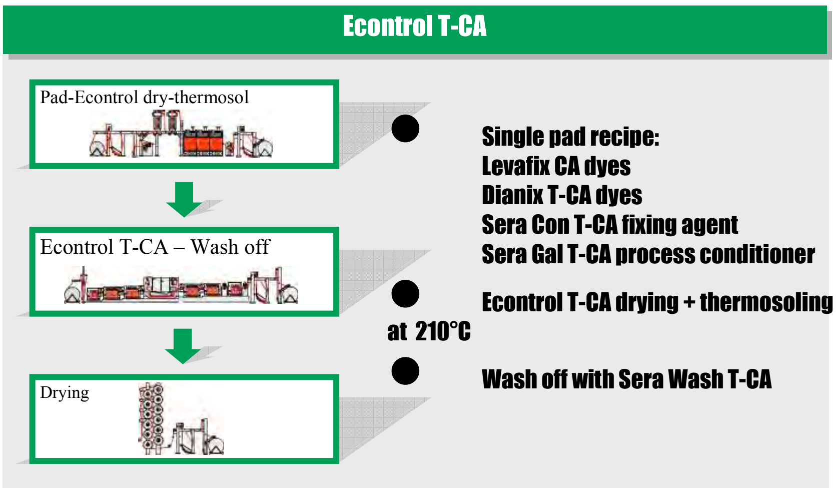

Fig. 6

The dye liquor contains all the dyes and the chemicals required for fixation. The process uses Levafix CA reactive dyes, which achieve an optimum dye yield under these conditions. In other words, there is no reduction in yield compared with conventional processes. (Fig. 7)

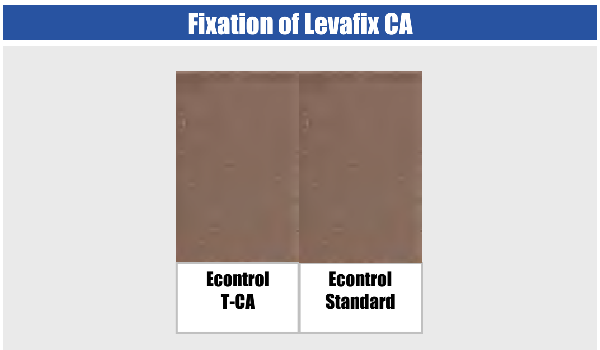

Fig. 7

Special Dianix T-CA dyes are used for the PES component in the blend. These newly developed products ensure optimum build-up in the specific Econtrol T-CA conditions (Fig. 8).

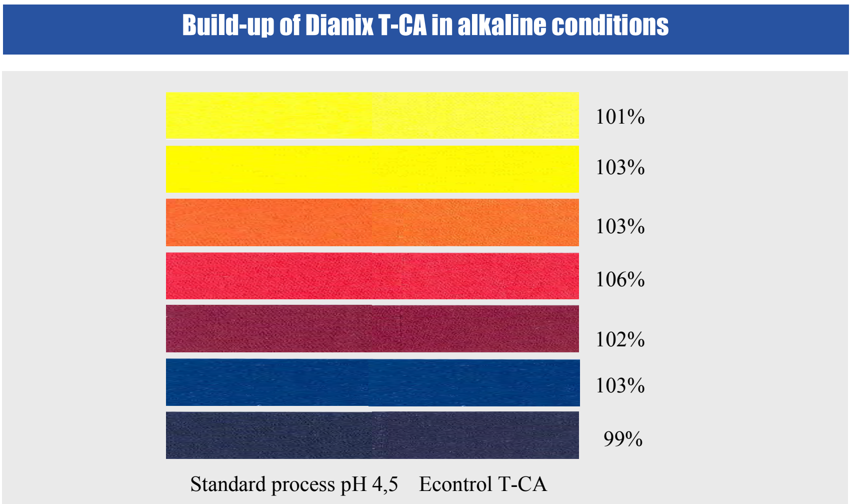

Fig. 8

Other additives are Sera fixing auxiliary and Sera process conditioner to ensure optimum fixation conditions for both Levafix CA and Dianix T-CA. This guaranties reproducible results in both the lab and production.

After application of the dyes, the goods are dried and thermosoled in special Econtrol conditions.

After thermosoling, the goods are fed directly into the washing unit. No further fixation steps are required.

Sera Fast T-CA has to be added to the wash-off liquor to make sure the dyeing meets the required fastness specifications.

After washing off, the goods are dried and processed as usual. The reminder here is that any type of additional thermal treatment can result in thermomigration and affect the fastness of the disperse dyes.

Economic and ecological aspects

Economy and ecology are often regarded as mutually exclusive in textile finishing. There is a tendency to believe that solutions that are ecologically acceptable entail higher costs.

The Econtrol T-CA process shows that precisely the opposite is true.

Obviously, reducing the amount of chemicals, water and energy required reduces their impact on both the environment and operating costs.

The consumption data for the Econtrol T-CA process clearly demonstrate its benefits: because it does not use separate baths and reduction clearing is not necessary, the process saves large amounts of chemicals, water and energy. The example given above shows a reduction of 86% in chemical consumption based on daily production of 20,000 m. The process also uses 63% less water and 49% less energy (Fig. 9).

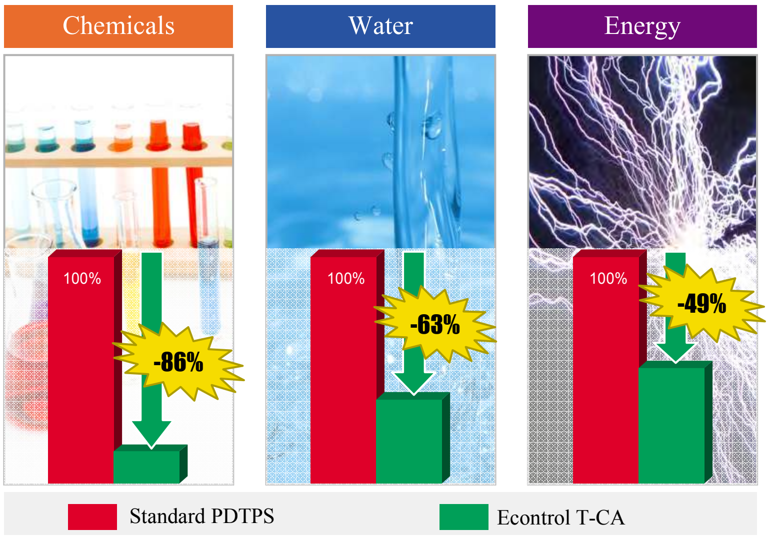

Fig. 9

These data are reflected in production costs. On this basis, the Econtrol T-CA process provides nearly 50% lower cost than standard production processes (Fig. 10).

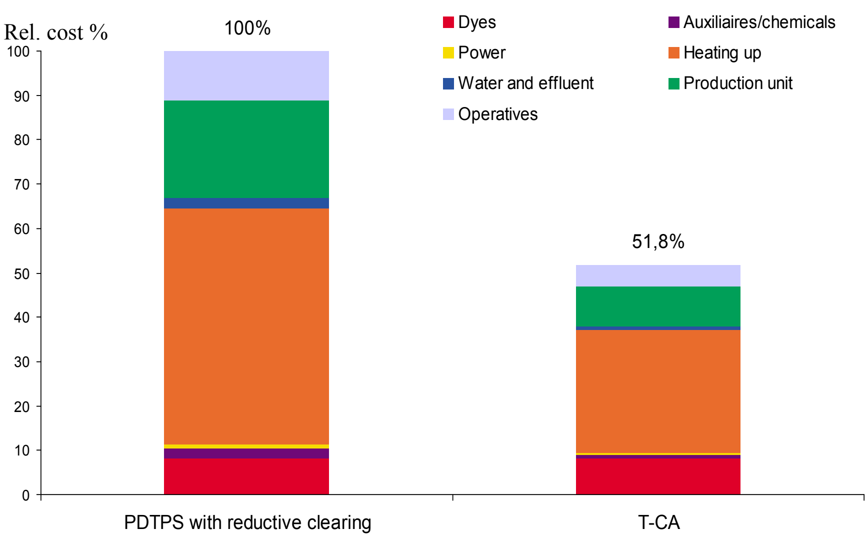

Fig. 10

Colour fastness

The objective for Econtrol T-CA was to develop an ecologically and economically acceptable process without any concessions in respect of wet fastness. However, the colour fastness requirements for PES/cellulosic vary greatly, depending on their use.

The objective of the Econtrol T-CA process was not to develop a solution for these highly specialised areas of workwear and sportswear. For these articles, it is more effective to use specialities developed specifically for such applications, i.e. Indanthren dyes for cellulosic fibres and Dianix XF/SF for polyester.

The following ISO 105 fastness tests were tested on a variety of materials and shades (multifibre adjacent fabric), with concentrations of up to 30 g/l dye.

- Light fastness B02
- Wash fastness C01 (40 °C)
- Wash fastness C02 (50°C)
- Wash fastness C03 (60°C)
- Wash fastness C06 C2S (60 °C with perborate)
- Water fastness, severe, E01
- Perspiration fastness alkaline + acid E04

Different blend ratios of Polyester and Cotton were used.

Fastness properties

The benchmark for the quality of this process is comparison with a two-bath dyeing with reduction clearing.

No difference was observed in light fastness compared with the standard process. Similarly, wash fastness tested in accordance with ISO 105 C01/C02/C03 (40°C/50°C/60°C) complies fully with the requirements for apparel (Fig. 11).

Fig. 11 Washing fastness 40°C/50°C/60°C

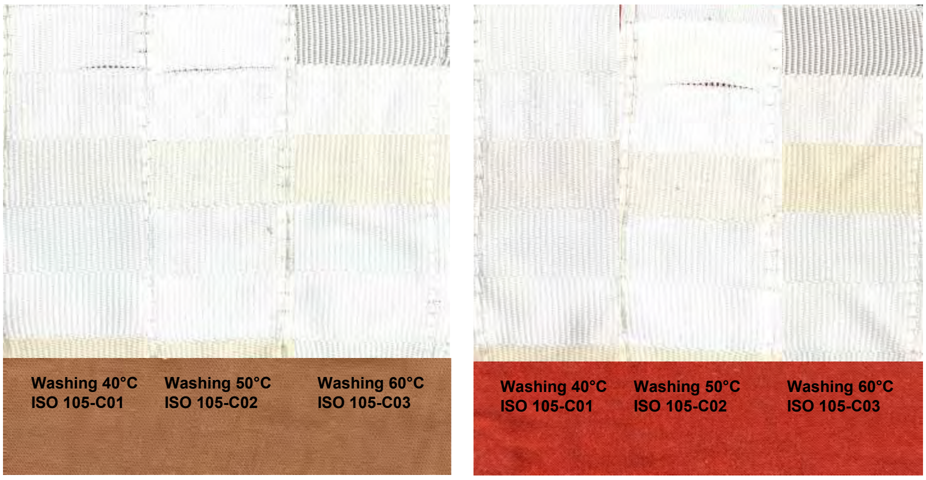

Fig. 11

In the C06 C2S wash fastness test, the specimen dyed using this process showed significant staining of polyamide in the multifibre adjacent. However, there was virtually no difference compared with the reference sample (with reduction clearing) (Fig. 12).

Water fastness, severe, and perspiration fastness (acid and alkaline) are equal or slightly below the reference dyeing (max. ½ grade).

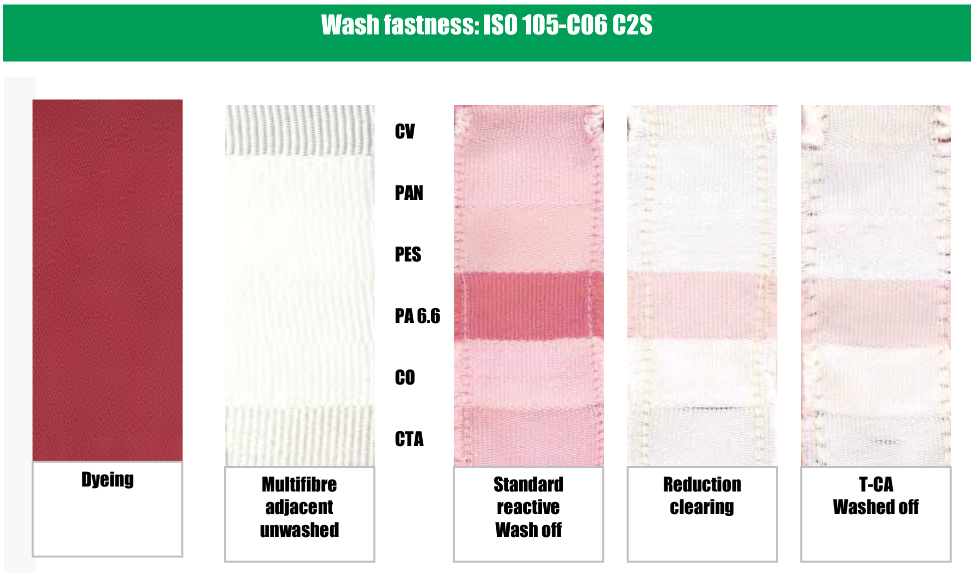

Fig.12

Options

So far, continuous dyeing of PES/cellulosic blends could only be used for woven fabrics. The Econtrol T-CA process combined with the Thermex® unit manufactured by Monforts extends continuous dyeing to knitgoods for the first time. Initial production trials have been very successful and Monforts will be exhibiting samples at ITMA 2007 in Munich (Fig. 13).

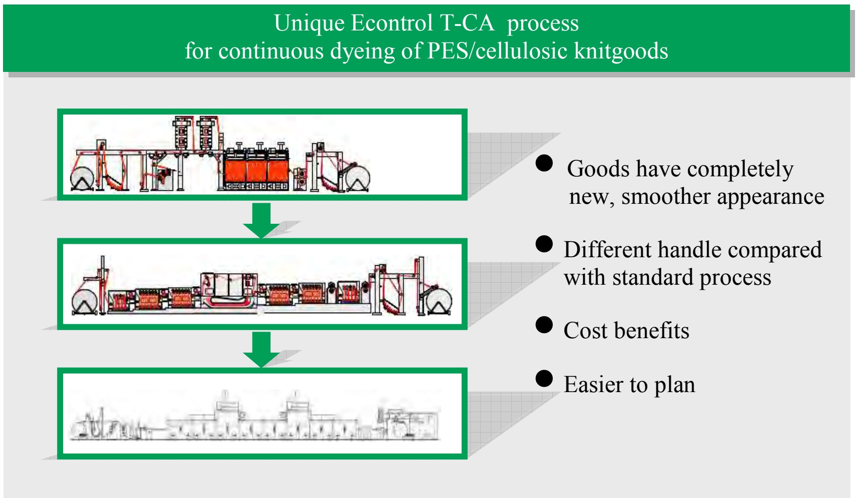

Fig. 13

Conclusion

Econtrol T-CA is a new, one-bath dyeing process for continuous coloration of wovens and knitgoods. A combination of Levafix CA dyes, newly developed Dianix T-CA dyes and Sera process auxiliaries, combined with smart machinery, can be used to dye shades with up to 30 g/l dye whilst making enormous savings in process costs, without reducing fastness.

Simple process regulation and carefully matched components ensure highly reliable recipes and thus good reproducibility.

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