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Continuous Dyeing Using Radio Frequency Energy

Part VI: The Effect of Anode Current and Dyeing Auxiliaries on the Dyeing of Wool

by

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CONTINUOUS DYEING USING RADIO FREQUENCY ENERGY
PART VI: THE EFFECT OF ANODE CURRENT AND DYEING AUXILIARIES ON THE DYEING OF WOOL

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ABSTRACT

The effect of RF generator anode current on the dyeing temperature and the effect of dyeing auxiliaries in the pad liquor on the dye fixation, fastness ratings and colour strength of wool dyed in an RF dyeing machine was investigated. It was found that acceptable dyeings were obtained at relatively low anode current settings (i.e. at relatively low temperatures). Furthermore, auxiliaries such as urea, thickening and de-aerating agents did not affect the dye fixation and washfastness ratings of RF dyed wool. More level dyeings were obtained, however, in the presence of thickening and de-aerating agents.

INTRODUCTION

Due to increasing labour and energy costs the optimisation of dyeing processes has become of vital importance to the textile industry[1]. Significant savings in energy have already been made by the optimisation of dyeing equipment and dyeing processes as well as by the introduction of new technologies. One development which has shown considerable potential is that based on radio frequency (RF) energy. In a recent update on the use of RF machines in the textile industry, it was shown, for example, that savings of more than 78% and 60% were obtained when wool, cotton and acrylic fibres were *dried* using RF energy, compared with conventional rapid and pressure driers, respectively[2]. This is in agreement with the findings by O'Connell[3] who reported savings up to 85% when RF energy was used for the drying of textiles.

The advantages associated with the drying of textiles using RF energy are of course also applicable to RF *dyeing* systems. It was shown that the energy consumption could be reduced significantly when RF energy was used for dyeing[4,5,6]. Furthermore, some preliminary studies showed that the amount of dyeing auxiliaries could be reduced, while some could even be omitted during RF dyeing[7]. The objective of the present study was to investigate the RF dyeing of wool in more detail, especially as far as the effect of generator output (anode current) on dyeing temperature and dye fixation was concerned. Furthermore, the effect of dyeing auxiliaries in the pad liquor on the quality of the dyed wool was investigated.

EXPERIMENTAL

Materials

Wool top with an average dichloromethane extractable matter content of 0,7%, a linear density of approximately 20 ktex and mean fibre diameter of 22 μm., was used.

Chemicals

Commercial grade dyes, chemicals and auxiliaries were used.

Treatments

RF dyeing was carried out on a 15 kg/hr Fastran Continuous Top Dyeing machine as was described previously[8]. An anode current ranging from 200 mA to 400 mA was used for dyeing at various temperatures.

In most cases 10g wool samples were padded to a wet pick-up of 80% with dye solution containing:

20 g/ℓ dye

1,5 g/ℓ CH_3COOH (pH 5,0)

2,0 g/ℓ ®Lameprint 651 (Thickener)

In some cases the thickener concentration was varied from 0 to 10 g/ℓ while for certain other experiments, de-aerating agents varying in concentration from 0 to 10 g/ℓ were added to the padding solution. After padding, the samples were placed in polyethylene bags and continuously carried through the RF tube by means of wool sliver which was padded to an 80% wet pick-up with water. The residence time in the tube was approximately 35 minutes in total, while the residence time between the electrodes was about 5 minutes.

Tests

The temperature attained by the wool fibres inside the tube at the various anode current settings was measured by means of IBV temperature strips and a thermo-couple.

Dye fixation was determined spectrophotometrically by measuring the absorbance of solutions obtained from soaping the dyed samples with ®Ultravon HD for 20 minutes at 100°C.

Colour fastness of the dyed samples to washing was determined according to the ISO-105-CO3-1978(E) method. The colour strength (K/S) values of the dyed samples were measured on a Micromatch 2000 Spectrophotometer.

RESULTS AND DISCUSSION

Effect of Anode Current on Dyeing Temperature and Dye Fixation

The Fastran machine can be operated at various anode current settings. Figure 1 shows the relationship between anode current and power consumption (kWh). An increase in the anode current leads to an increase in energy generation and thus to an increase in temperature in the dyeing tube up to a certain point, whereafter no further increase takes place. This is clearly illustrated in Figure 2 which shows that the temperature reaches a maximum value of 110°C at an anode current of 350 mA. The observation that the temperature could not be increased to values higher than 110°C is possibly due to the fact that the dyeing tube is not completely sealed or pressurised and consequently some steam escapes from the tube during dyeing. It is clear, however, that within the temperature range 50°C to 110°C, any specific dyeing temperature can be selected by an appropriate setting of the anode current.

In order to establish the minimum anode current (the lowest temperature) at which acceptable dye fixation values could be obtained, wool was treated with reactive, acid and metal-complex dyes at various anode current settings varying from 200 to 400 mA. The dye fixation values obtained are shown in Figure 3. It is clear that equilibrium dye fixation values were obtained at relatively low anode current values (i.e. low temperatures). In general, an anode current of 300 mA (i.e. a temperature of 100°C) gave acceptable dye fixation values for most dyes and there is clearly no reason for increasing the anode current to 400 mA which merely results in energy being wasted.

At an anode current of 300 mA only 0,642 kWh is required (Fig. 1) for acceptable dye fixation, instead of the 1,07 kWh which is used at an anode current setting of 400 mA. This reduction in the anode current consitutes a saving of about 40% in power consumption. If an anode current of 350 mA which should suffice for most dyes, is used, the saving in power consumption would still amount to approximately 20%. Figure 3 also shows that there were significant differences between the different dyes, with some acid dyes producing relatively high fixation values at temperatures as low as 50°C.

The colour strength (K/S values) of the dyed samples were determined and are given in Table 1. It is clear that, in general, the K/S values of the wool dyed at an anode current of 300mA (i.e. a temperature of 100°C) were similar to those of fibres dyed at 400 mA (a temperature of 110°C). The tendencies observed for dye fixation were thus also reflected in the colour strength (K/S value) of the dyed wool samples.

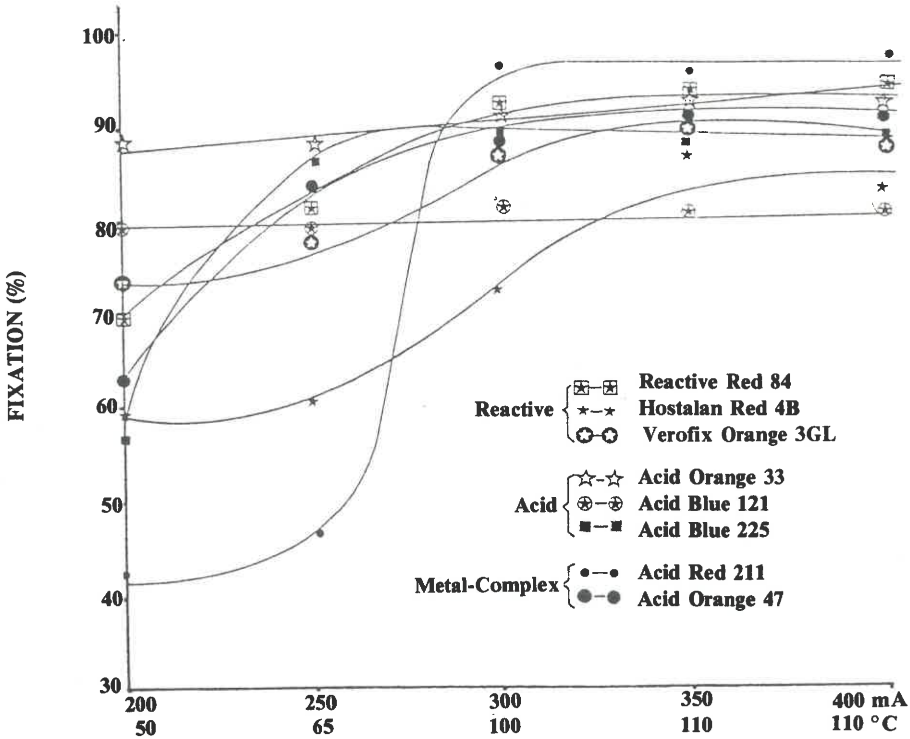

Fig. 3 – Relationship between temperature and dye fixation for various dyes during RF dyeing.

TABLE 1

THE EFFECT OF ANODE CURRENT ON THE COLOUR STRENGTH (K/S) OF WOOL RF DYED WITH VARIOUS TYPES OF DYES

Anode Current (mA)	Tempe-rature (°C)	COLOUR STRENGTH (K/S)							
		Reactive Dyes			Acid Dyes			Metal Complex Dyes	
		Reactive Red 84	®Hostalan Red 4B	®Verofix Orange 3GL	Acid Orange 33	Acid Blue 129	Acid Blue 225	1 : 2	1 : 1
								Acid Red 211	Acid Orange 47
200	50	2,4	3,6	4,0	3,5	4,0	2,2	1,4	3,0
250	65	2,3	3,7	4,1	3,8	3,8	3,0	2,6	2,9
300	100	3,6	3,6	4,1	3,9	3,9	4,0	3,4	3,2
350	110	3,6	3,9	4,2	4,1	3,9	—	3,4	3,3
400	110	3,7	4,1	4,4	4,0	3,9	3,8	3,3	3,4

Effect of Dyeing Auxiliaries

(i) Urea

It is well-known that urea enhances the rate of dyeing and the fixation of dyes on wool, especially at low temperatures[9]. The actual mechanisms involved have not yet been fully elucidated but it has been proposed that urea acts by disaggregation of the dye molecules, by causing preferential dye absorption onto the fibre as well as by forming weak complexes with the dye so that binding to the fibre occurs on sites not normally available[10].

Although as much as 300 g/ℓ urea is usually used in pad liquors, it was decided to use 100 g/ℓ urea in the present study since Graham and Holt[11] showed that this level of urea gave acceptable results when RF dyeing was carried out according to the IWS Lanapad process. Furthermore, it was found in the present investigation that increasing amounts of urea in the pad liquor increased the pH of the wool dyed in the Fastran machine (Table 2). This increase in pH was probably due to the break down of urea at high temperatures.

TABLE 2

THE pH VALUE OF WOOL DYED IN THE PRESENCE OF INCREASING CONCENTRATIONS OF UREA

UREA (g/ℓ)	pH
0	5,5
10	7,2
20	7,6
50	7,9
100	8,2

In order to establish whether the presence of urea in the dye liquor would increase the fixation of dyes on wool during RF dyeing, a number of trials were carried out over a range of temperatures using a reactive dye (Reactive Red 84). The results are given in Table 3.

It is shown in Table 3 that urea had practically no effect on the fixation of the dye irrespective of the dyeing temperature. Furthermore, the presence of urea in the dye liquor had no effect on the levelness of dyeing.

TABLE 3

THE EFFECT OF UREA ON DYE FIXATION AT VARIOUS ANODE CURRENT SETTINGS

Anode Current (mA)	Temperature (°C)	Dye Fixation (%)	
		0 g/ℓ Urea	100 g/ℓ Urea
200	50	69,3	71,7
250	65	81,6	80,1
300	100	90,8	90,2
350	110	92,8	95,5
400	110	95,1	94,8

(ii) Thickening agent

It is common practice to use auxiliaries such as thickening and de-aerating agents during pad dyeing, mainly to increase the levelness of dyeing and to prevent dye migration. In order to evaluate the effect of thickener on the levelness of dyeing and dye fixation, wool was dyed in the RF machine using a mannogalactan ether type thickener. It was found that the presence of thickening agent in the pad liquor did improve the levelness of dyeing, even at concentrations as low as 1 g/ℓ. There was practically no difference between the levelness of the samples treated with different concentrations of thickener. The effect of various concentrations of this thickener on dye fixation and washfastness ratings is given in Table 4.

TABLE 4

THE EFFECT OF VARIOUS CONCENTRATIONS OF THICKENING AGENT ON DYE FIXATION* AND WASHFASTNESS RATINGS

Thickener Conc. (g/ℓ)	Viscosity (Pa.s)	Fixation (%)	ISO 3 WASHFASTNESS		
			Effect on Shade	Staining Cotton	Staining Wool
0	$1,5 \times 10^{-3}$	90,8	4-5	5	5
1	4×10^{-3}	92,5	4-5	5	5
2	15×10^{-3}	93,1	5	5	5
10	2200×10^{-3}	89,6	4-5	5	5

* CI Reactive Red 84

The results in Table 4 show that the thickening agent had practically no effect on the dye fixation and washfastness ratings of the wool.

The viscosity of padding liquors depends, amongst other things, on temperature and generally decreases with increasing temperature. It is possible, therefore, that the levelness of dyeing could be affected by the temperature of the pad liquor. In order to establish whether this was true in the case of RF dyeing, wool was padded with dye liquors containing 2 g/ℓ thickener at temperatures varying from 20° C to 60° C and then passed through the Fastran machine. It was found that all the dyeings were level. Furthermore, the pad liquor temperature had no effect on the fixation and washfastness ratings of the dyed wool (Table 5).

TABLE 5

THE EFFECT OF PADDING LIQUOR TEMPERATURE ON DYE FIXATION* AND WASHFASTNESS

Temperature (°C)	Viscosity (Pa.s)	Fixation (%)	ISO 3 WASHFASTNESS		
			Effect on Shade	Staining Cotton	Staining Wool
20	15×10^{-3}	93,1	5	5	5
37	$14,5 \times 10^{-3}$	90,0	5	5	5
50	11×10^{-3}	92,0	4-5	5	5
60	9×10^{-3}	91,7	5	5	5

* CI Reactive Red 84

(iii) De-aerating agents

Finally the effect of de-aerating agents in the dye liquor on the RF dyeing of wool was determined. The purpose of de-aerating agents during padding is to remove air from the liquor, i.e. they suppress foam formation. Furthermore, they assist the penetration of the pad liquor into the goods and thus increase liquor uptake. The results are given in Table 6.

It seemed that the presence of de-aerating agents in the pad liquor did improve the levelness of dyeing marginally. Table 6 shows, however, that de-aerating agents had practically no effect on dye fixation and washfastness ratings of RF dyed wool.

TABLE 6

THE EFFECT OF DE-AERATING AGENTS ON DYE FIXATION AND WASHFASTNESS OF RF DYED WOOL*

De-Aerating Agent (%)	Fixation (%)		ISO 3 Washfastness					
			Effect on Shade		Staining Cotton		Staining Wool	
	®Irgapadol FFU	®Albegal FFD	®Irgapadol FFU	®Albegal FFD	®Irgapadol FFU	®Albegal FFD	®Irgapadol FFU	®Albegal FFD
0	89,3	91,9	5	5	5	5	5	5
5	88,4	89,6	4-5	4-5	5	5	5	5
10	88,3	90,8	4	5	5	5	5	5

* CI Reactive Red 84

SUMMARY AND CONCLUSIONS

In this study the effect of various parameters such as variations in the anode current, the temperature of dyeing and the presence of certain auxiliaries in the liquor on the levelness of dyeing and some fastness properties of wool dyed in an RF dyeing machine was investigated.

It was found that the dyeing temperature increased with increasing anode current up to a value of 350 mA whereafter there was no further increase. Dye fixation reached a maximum at an anode current of 300 mA i.e. temperature of 100° C for most dyes. Compared to dyeings carried out at an anode current of 400 mA, a saving of about 0,4 kWh energy was obtained by reducing the anode current to 300 mA. Although equilibrium dye fixation was generally attained at an anode current of 300 mA (100° C), certain dyes showed maximum dye fixation at anode currents as low as 200 mA, i.e. at temperatures as low as 50° C.

Finally it was found that the addition of urea, a well-known swelling agent for low temperature dyeing treatments, to the dye liquor, had no beneficial effect on dye fixation during RF dyeing. The presence of auxiliaries such as thickening and de-aerating agents in the dye liquor improved the levelness of dyeing, but had no beneficial effect on the percentage dye fixation and washfastness ratings of RF dyed wool.

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USE OF PROPRIETARY NAMES

The names of proprietary products where they appear in this report are mentioned for information only. This does not imply that SAWTRI recommends them to the exclusion of other similar products.

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