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PREVENT REDEPOSITION OF SOLID IMPURITIES DURING WASHING SYNTHETIC FABRICS

ABSTRACT

The textile washing process involves basically of three stages :1) removing the soiling from the substrate, 2) suspending the soling removed in the washing bath and 3) preventing redeposition of the soiling onto the substrate from which has just been removed. In fact soiling removed from the substrate may deposited onto it a greater or lesser extent during the detergent process, as unwanted phenomenon that can be avoided by using appropriate polymers. Preventing the redeposition of impurities is especially important during the washing of synthetic fibres with a compact crystal structure such as polyester or acrylics.

The primary purpose of this work was assess the performance of a polyethylene glycol polyester copolymer used as a detergent additive to prevent redeposition of solid impurities during the washing of standard polyester and acrylic fabrics in terms of the zeta potential of the fabrics. The copolymer was used in combination with the anionic surfactant, sodium dodecylbenzenesulphonate (SDBS) the non-ionic surfactant fatty alcohol ethoxylate with 7 m.E.O., or both in variable proportions. The soiling used as a solid impurity in the washing process was carbon black. The observed behaviour is explained in terms of the electrical double layer of the fabrics, which was characterized separately with each surfactants and their mixture.

Key words: fabrics, washing, anti-redeposition agent, anionic surfactant, non-ionic surfactant, polyester and acrylic fabrics and zeta potential.

INTRODUCTION

The washing of textiles involves three prior elements in the detergency process, namely 1) the substrate (the surface to be cleaned), 2) the soiling (the undesired material on the substrate that must be removed) and 3) the washing solution or "bath" (the liquid brought into contact with the substrate). The washing process using detergent consists basically of three stages, namely 1) removal of the soiling from the substrate, 2) suspension of the soiling in the bath and 3) prevention of redeposition of the soiling on the substrate.[Lange K.R. 1994]

Consumer demand for the detergents used in home washing requires a variety of components, which may be classed in three groups: surfactants, builders and additives. Through their specific actions all those components contribute to attaining the objectives of textile detergency. There are notable synergistic effects that result from certain components, mainly mixtures of surfactants. [Falbe J. editor 1987]

The soiling impurities that are removed may be deposited again on the substrate to a greater or lesser extent during the washing process. This phenomenon constitutes the unwanted redeposition of that impurity on the substrate. [Carrion Fité F.J.,1987]

Anti-redeposition agents must be added to the wash (as a further detergent additive) to prevent redeposition of impurities, in the form of water-soluble polymers that can interact with the anionic surfactants and reduce the occurrence of redeposition of impurities during the wash. Likewise, the non-ionic surfactant can stabilise the polymer and improve its action during the wash. [Carrion Fité F.J.,1982]

In the washing of synthetic fibres such as polyester or acrylic, which have a compact crystalline structure, measures must be taken to prevent the redeposition of impurities.

In a washing bath most of the textile substrates and particles of impurities are negatively charged and their surface is therefore covered by an electrical double layer with its corresponding zeta potential. [Verwey E.J.W. and Overbeek J.Th., 1948]

The zeta potential of the fibre is determined by the following factors: a) the fibre, depending on whether it is physically or chemically modified, and b) the polar medium, which will vary according to the nature of the electrolytes and surfactants in the aqueous solution. [Derjawin B.V., Landau L.D., 1940]

The purpose of this work is to ascertain the behaviour of the polyethylene glycol polyester copolymer when used as an additive in detergents to prevent redeposition of impurities during the washing of standard polyester and acrylic textiles. Those polymers were used in washing tests in the presence an anionic surfactant, SDBS, and a non-ionic surfactant, fatty alcohol ethoxylate (AE) with 7 moles E.O., separately and in mixtures of both with varying proportions. The soiling applied during the redeposition test washing was carbon black, as a solid impurity in washing. In order to explain the observed behaviour, the electrical double layer of the fabrics was characterised, depending on the surfactants and the mixtures tested.

EXPERIMENTAL

Materials

Fabric

Acrylic fabric: Standard Style 864 Orlon 75 from Testfabrics Inc., Middlessex, New Jersey, USA[ISO 105-F10].

Standard polyester fabric, Type 30 A (Code 30000) from wfk Testgewebe GmbH (Germany) [ISO 105-F10].

Chemicals

Surfactants

The following surfactants were used:

a) Anionic surfactant: sodium dodecylbenzenesulfonate (SDBS) with 80% pure active ingredient, reagent for analysis, supplied by Sigma.

b) Non-ionic surfactant: fatty alcohol ethoxylate with 7 m. E.O. (AE-7) with 100% active ingredient, named Synperonic A7, supplied by Croda.

Anti-redeposition agent

The anti-redeposition agent used was:

a) Polyethylene glycol polyester copolymer (1,4-benzenedicarboxylic acid polymer with Alpha-Hydro-omega-hydroxypoly(oxy-1,2-ethanediyl), called Sorez-100, supplied at a concentration of 76.3% polymer by International Speciality Products (USA), distributed by ISP Co. Ltd. (UK) [Catalogue ISP international Specialty Products]

Solid impurity

The solid impurity used was Raven 1040 carbon black from Columbian, with a particle diameter of 29 nm and surface area of 85 $m^2 \cdot g^{-1}$, suitably dispersed in isopropyl alcohol in the washing baths by means of a vibro-agitator.

Water

The water used for the washing solutions was commercial distilled water passed through a Milli-Q inverse osmosis apparatus. [UNE 55 524/92]

Apparatus

Washing apparatus

A Launder-Ometer from Atlas Instruments (USA) was used for the washing tests.

Spectrophotometer

The reflectance of the fabrics was measured using a Color i7 spectrophotometer running Color i7 software from X-Rite Incorporated (USA), equipped with a Xenon D65 lamp and with a measurement range of 360 to 750 nm at intervals of 10 nm, repeatability 0.01 RMS ΔE CIELAB. [AATCC Test Method 153-1985]

Equipment for measuring zeta potential

The zeta potentials of the standard fabrics were measured by the flux potential method using an EKA electrokinetic analyser from Anton Paar (Austria).

Procedures

Prior fabric washing

To ensure the cleanliness of the standard acrylic (Orlon) and polyester fabrics, they were first washed using Sandozin NIA at a concentration of 0.5 $g.L^{-1}$, at a temperature of 40ºC for 30 minutes.

Washing methodology

The surfactants used were sodium dodecylbenzenesulfonate (SDBS) and fatty alcohol ethoxylate with 7 m. E.O. (AE-7) in the following anionic: non-ionic molar ratios: 1:0, 0.8:0.2, 0.6:0.4, 0.4:0.6, 0.2:0.8 and 0:1, with a total concentration 5 x 10^{-3} M for the mixture.

The tested anti-redeposition agent Sorez 100 was applied to the different proportional mixtures of surfactants at a concentration of 0.0725 $g.L^{-1}$

Washing conditions: The fabrics were washed in the Launder-Ometer with 500 ml specimen containers:

a) Fabric swatches: 10 x 4 cm polyester and acrylic fabrics

b) Total surfactants concentration: 5×10^{-3} M of surfactants, separately and mixed

c) Concentration of solid impurity in the washing bath: 2.5 ml of solution of carbon black in isopropyl alcohol of 4 $g.L^{-1}$, therefore 10 mg added for each test, giving 0.0666 $g.L^{-1}$. To determine the influence of variation of the concentration of carbon black, a range of concentrations of 0.0666 $g.L^{-1}$ to 0.2 $g.L^{-1}$ was established.

d) Washing bath: 150 ml [ISO Standard 105-106/DAD1]

e) Washing temperature: 40ºC

f) Washing time: 30 minutes

g) pH: 6

Measurement of soilinging of the fabrics

The degree of soiling (due to deposition during washing) of the clean fabric after washing was determined in terms of the tristimulus values X, Y and Z obtained from the reflectance measurements of the fabric. The formula was as follows [Florio F.A.and Merserau E.P., 1955]:

$$\Delta C = \{ (X_S - X_P)^2 + (Y_S - Y_P)^2 + (Z_S - X_P)^2 \}^{½} \qquad (1)$$

where X_p, Y_p and Z_p are the tristimulus values for the fabric before washing and X_s, Y_s Z_s are the tristimulus values for the unsoiled fabric after washing. Those values are the average of four reflectance readings obtained with rotation of the sample through 90º for each measurement.

At the same time the whiteness of the fabrics were measured according the CIE whiteness index and assessment of the corresponding tint. (ISO 105-JO1:1997/UNE-EN ISO 105-J01:feb 2001)

Measurement of zeta potential

The zeta potential ζ of the fabric was determined by means of the streaming potential method based on the circulation of the flow of the solution through the surface of the fabric. The fabric, in the form of 15 circles with a diameter of 2 cm, was placed in the cylindrical measurement cell equipped with Ag/AgCl electrodes. Measurement of the zeta potential ζ was based upon a linear ratio between the potential of the electrodes and a flow of liquid, measured as the pressure difference (p) using the Helmholtz-Smoluchowski equation (2) given below, calculated using the software accompanying the Anton Paar EKA equipment [Manual operating].

$$\zeta = \frac{dU}{dp} \cdot \frac{\eta}{\varepsilon \cdot \varepsilon_o} \cdot \kappa \cdot 10^{-8} \qquad (2)$$

where: ζ is in mV; dU/dp (mV/mbar) is the slope of the flow potential depending on the pressure in the measurement cell; η (mPas) is the viscosity of the solution; ε_o is the dielectric constant of the solution; ε (F/m) is permittivity and κ is the conductivity of the solution.

Relationship between degree of soiling and amount of carbon black deposited on the polyester and acrylic fabrics

The relationship between the degree of soiling and the amount of carbon black deposited was evaluated using the Florio-Merserau equation [Florio F.A.and Merserau E.P., 1955] based on the reflectances (measured as tristimulus values) of the polyester and acrylic fabrics and the logarithm of the amount of carbon black deposited, expressed as mg of carbon black per m^2. The surfactant SDBS was used at a concentration of 5 $x10^{-3}$ M and known amounts of carbon black were applied to the fabric to obtain the corresponding fits between the reflectances and the logarithm of the amount of carbon black deposited. The linear fits obtained for the polyester and acrylic fabrics are shown in the table below.

RESULTS AND DISCUSSION

Deposition of carbon black on polyester and acrylic fabrics after washing: influence of the anti-redeposition agent

The amounts of carbon black deposited on the polyester and acrylic fabrics in the presence of the surfactants SDBS and fatty alcohol ethoxylate with 7 m. E.O. (Synperonic A7), with and without Sorez 100, are shown in Figures 1 and 2 below and their CIE whiteness index indicated in Figures 3 and 4 respectively , respectively. The surfactants were used separately and together in the proportions SDBS:non-ionic of 1:0, 0.8:0.2, 0.6:0.4, 0.4:0.6, 0.2:0.8 and 0:1.

Fig. 1 and 2.

Fig. 3 and 4.

Figures 1 and 3 show that without the anti-redeposition agent, the highest values for redeposition on both the polyester and acrylic fabrics were obtained in the presence of SDBS and the lowest with the non-ionic AE with 7 m. E.O. In the presence of the anti-redeposition agent those values for deposition dropped to insignificant levels for both the polyester and acrylic fabrics. They remained slightly higher with the SDBS, compared to the AE with 7 m. E.O.

Those figures also show that the values for deposition on the polyester and acrylic fabrics with the use of mixtures of the surfactants SDBS and AE with 7 m. E.O. in different proportions diminished with the increase of the concentration of the non-ionic surfactant in the mixture to the point of attaining values similar to those for use of that surfactant separately. Addition of the anti-redeposition agent Sorez 100 to the tested mixtures lowered the redeposition values to nil for the polyester fabric and practically zero for the acrylic fabric. This indicates that Sorez 100 is an effective anti-redeposition agent for use with synthetic fibres.

In the Figures 2 and 4 show the CIE whiteness index for polyester and acrylic fabrics respectively, of the same samples indicated in the Figures 1 and 3 and we can see that lower redeposition values implies higher whiteness and the same tendencies indicated for the

Figures 1 and 4 explained before, so the addition of Sorez 100 implies (lower redeposition values) higher whiteness index for polyester and for acrylic fabrics. The tint deviation according CIE whiteness index was without significance, so without tinted fabrics after redeposition testing, all the tint values were lower than ±03 (the corresponding tint value with significance coloristic meaning will be between ±0,5 and ±5,5 (Ganz E. and Griesser R.)).

Figure 5 shows the deposition behaviour for the amount of carbon black in the washing of the polyester fabric at different initial concentrations of that impurity, starting at the initial concentration of 0.066 $g.L^{-1}$ and increasing it up 0.2 $g.L^{-1}$, depending on the different proportions of the surfactants tested (SDBS and fatty alcohol ethoxylate with 7 m. E.O.). Those results indicate that for each concentration of carbon black tested the same trend was noted with regard to the surfactants used separately and in mixtures as mentioned above, with the particularity that the deposition of carbon black was greater with the SDBS that with the AE with 7 m. E.O. Therefore, variation in the concentration of the carbon black solid impurity added to the washing bath did not affect the previously mentioned behaviour of deposition of impurities depending on the different proportions in the mixtures of the anionic and non-ionic surfactants and the surfactants used separately.

Fig. 5

Figure 6 shows the effectiveness for all the proportions of mixture of the anionic and non-ionic surfactants and those surfactants separately with addition of the anti-redeposition agent Sorez 100 (concentration of 0.0725 $g.L^{-1}$) at the highest (0.2 $g.L^{-1}$) and lowest (0.0666 $g.L^{-1}$) concentrations of carbon black tested. Given those results, the effectiveness of Sorez 100 in the reduction of deposition of carbon black at those concentrations is evident, in keeping with the trends mentioned above depending on the proportions of mixture or the surfactants tested and the surfactants separately.

Fig. 6

Zeta potentials of acrylic fabric in the presence of SDBS and AE with 7 m. E.O with and without Sorez 100

Figure 7 shows the zeta potentials of the polyester fabric in the presence of SDBS and AE with 7 m. E.O. separately and in mixture, with and without Sorez 100, in aqueous solution with pH 6. Those results indicate that the highest (absolute value) zeta potential was found with the SDBS and the lowest with the AE with 7 m. E.O. The mixtures of the two gave intermediate values. Addition of the anti-redeposition agent Sorez 100 resulted in lower values for zeta potential (taken as absolute values as they all have the same sign) in the presence of the proportions of surfactants tested and the surfactants separately. Figure 8 shows the zeta potentials for the acrylic fabric in the same tests as shown in Figure 7. The variation in the zeta potential for the acrylic fibre depending on the surfactants used and their mixtures was the same as for the polyester fabric but with lower values, in general, for the zeta potential in all the tests.

The variations in the zeta potential with and without the addition of Sorez 100 may be explained as a result of the negative charge of the surfactant SDBS giving higher values for the zeta potential on both the polyester and acrylic fibres and making them more hydrophobic. This caused more carbon black to be deposited on their surfaces than in the presence of the non-ionic surfactant. [Carrion -Fité, 1993]. The zeta potential of the polyester and acrylic fabrics was lower (as an absolute value) in the presence of the non-ionic surfactant and the redeposition value was therefore lower in the presence of the non-ionic surfactant tested, given the lower hydrophobicity. This phenomenon may be explained by hydrophilic groups (ethylene oxide groups) of the non-ionic surfactant adhering to the surface of both the polyester and acrylic fibres and then being oriented towards the washing bath, slightly reducing the hydrophobicity of the substrate. [Tokiwa F. and Imanura T., 1984] The mixtures of the two surfactants gave intermediate values in comparison with the values for the surfactants used separately and the values for zeta potential and deposition both decreasing with the reduction of the amount of SDBS in the mixture and, consequently, increasing in proportion to the amount of the non-ionic surfactant. [Carrion -Fité, 1993] In all the tests, the presence of Sorez 100 reduced the zeta potential of both the polyester fabric and the acrylic fabric and therefore made them less hydrophobic, resulting in less deposition of impurities

Fig. 7 and 8.

CONCLUSIONS

We may make the following observations on the influence of the polyethylene glycol polyester copolymer (Sorez 100) as an agent to prevent redeposition of impurities during the washing of synthetic fibres such as polyester or acrylic in the presence of the surfactants SDBS and AE with 7 m. E.O, both separately and in anionic:non-ionic mixtures:

1) The polyethylene glycol polyester copolymer (Sorez 100) was effective as an agent to reduce the deposition of carbon black as an in impurity in the washing of synthetic fibres at the concentrations of carbon black tested.

2) The highest values for deposition of carbon black were obtained in the presence of the SDBS and the lowest values with the non-ionic surfactant AE with 7 m. E.O., in both cases without the anti-redeposition agent. In the presence of the anti-redeposition agent Sorez 100, those values dropped to insignificant levels nearing zero in all cases.

3) For the surfactant mixtures of SDBS and AE with 7 m. E.O, the deposition values decreased with the higher concentration of the non-ionic surfactant in the mixture to the point of attaining values similar the case of that surfactant used alone. Addition of the anti-redeposition agent Sorez reduced the deposition values to insignificant levels nearing zero in all cases. In the same way the whiteness index in the same samples increases with the addition of anti-redeposition agent indicated Sorex 100) and without changes in the tint parameter found.

4) With both the polyester and acrylic fabrics, in the absence of the anti-redeposition agent the highest zeta potential (absolute value) was found for the SDBS and the lowest for the AE with 7 m. E.O., and the mixtures of the two gave intermediate values. Therefore, the hydrophobicity of the textile substrate increased with the anionic surfactant SDBS and decreased with the non-ionic surfactant, along with the deposition of carbon black observed in all cases.

5) Addition of the anti-redeposition agent Sorez 100 in the washing tests resulted in lower zeta potential values for the tested fabrics. Consequently, they were made less hydrophobic and lower values were obtained for deposition of carbon black with the surfactants used and their mixtures.

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Table I

Linear fit between the degree of soiling and the logarithm of the concentration of carbon black deposited.

Fabric	Linear fit	Correlation coefficient
Standard polyester 30 A	y = 35.65x	0.98
Standard acrylic Style 864 Orlon 75	y = 48.94x	0.99

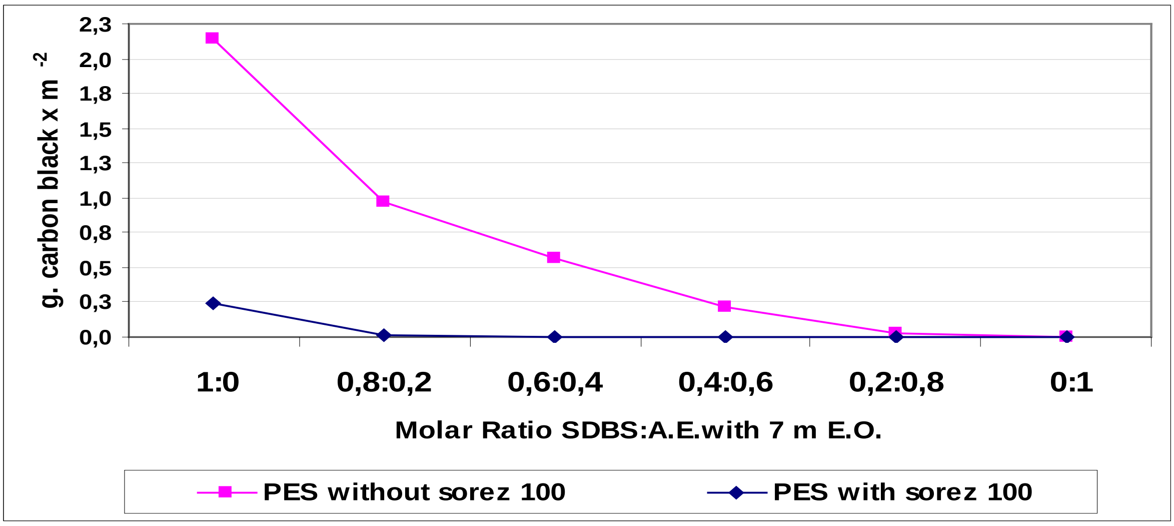

Figure 1. Deposition of carbon black (g.m-^{2}) on the polyester fabrics, respectively, depending on the proportions of anionic:non-ionic surfactants (SDBS:AE with 7 m. E.O.) at a total concentration of 5 x 10^{-3} M and temperature of 40ºC with and without Sorez 100, at the initial concentration of carbon black of 0.066 g.L^{-1}

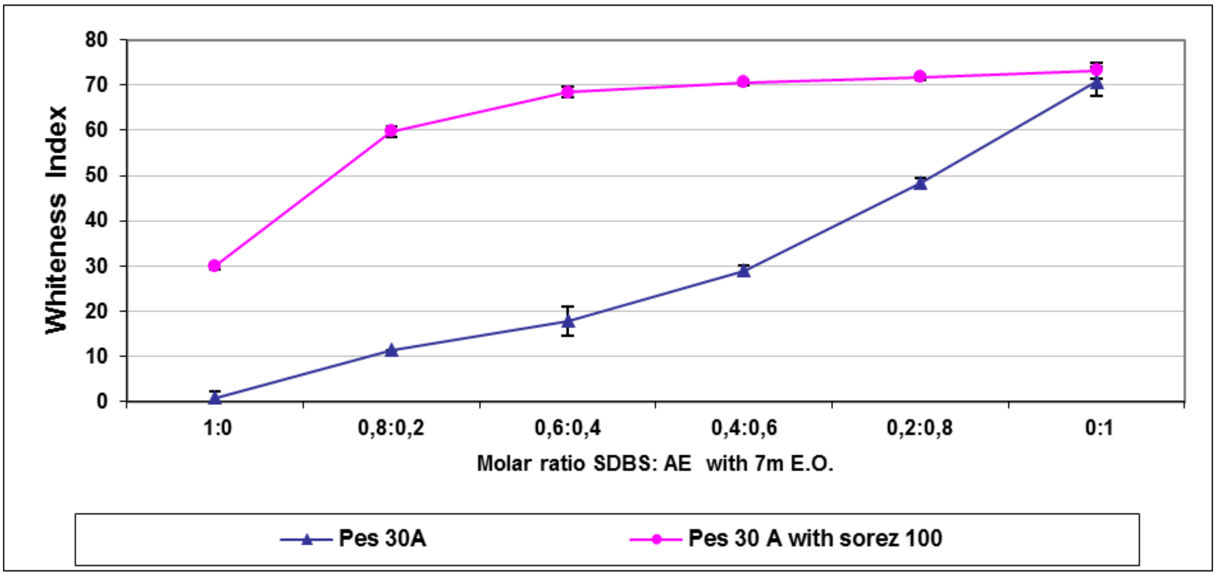

Figure 2. Whiteness Index on the polyester fabrics, respectively, depending on the proportions of anionic:non-ionic surfactants (SDBS:AE with 7 m. E.O.) at a total concentration of 5 x 10^{-3} M and temperature of 40ºC with and without Sorez 100, at the initial concentration of carbon black of 0.066 $g.L^{-1}$

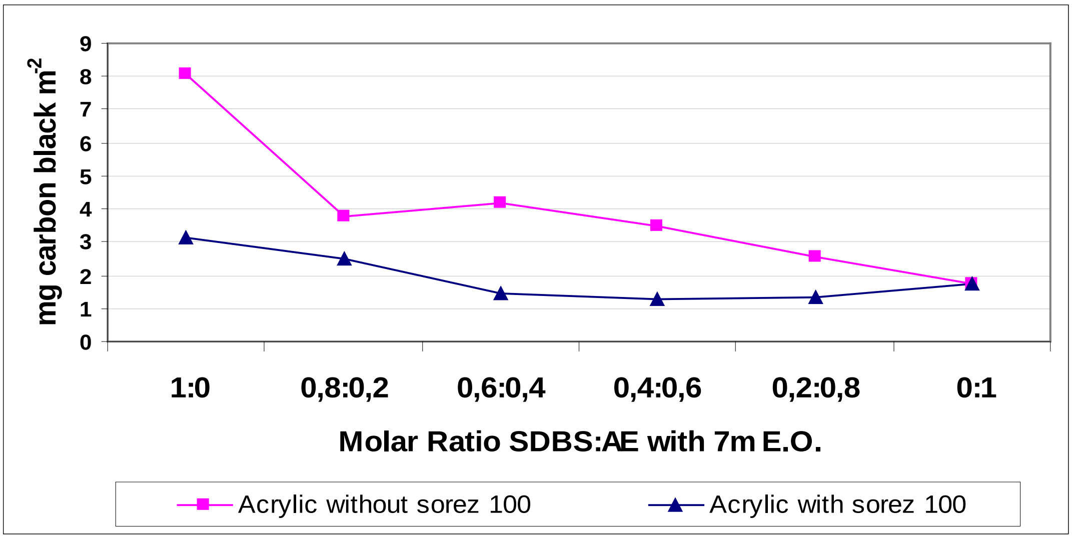

Figure.3 The same as the Figure 1 on the acrylic fabrics

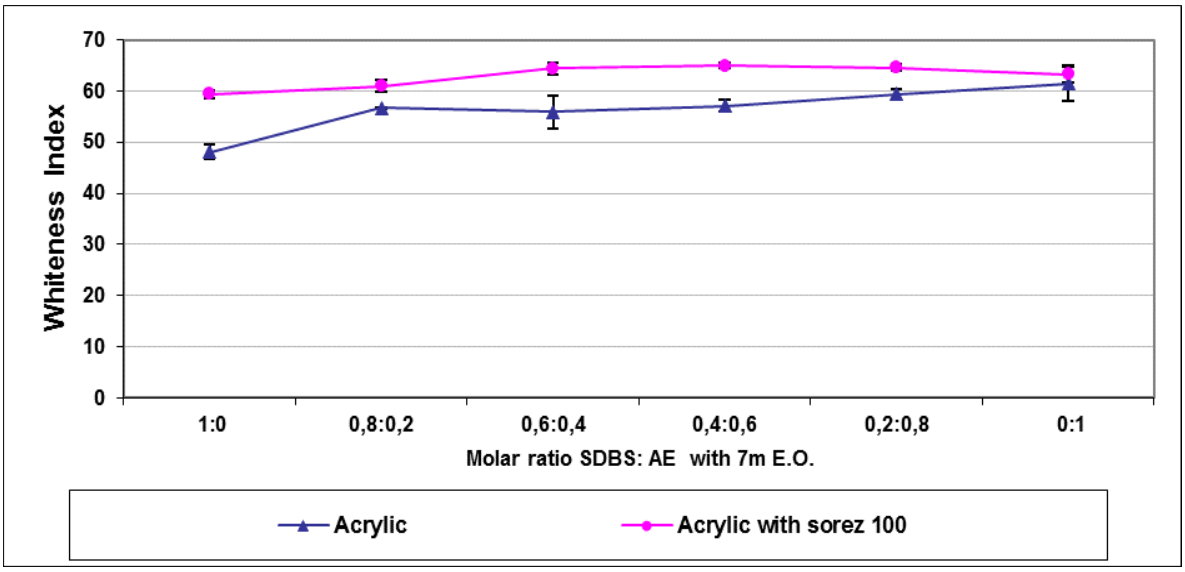

Figure.4 The same as the Figure 2 on the acrylic fabrics

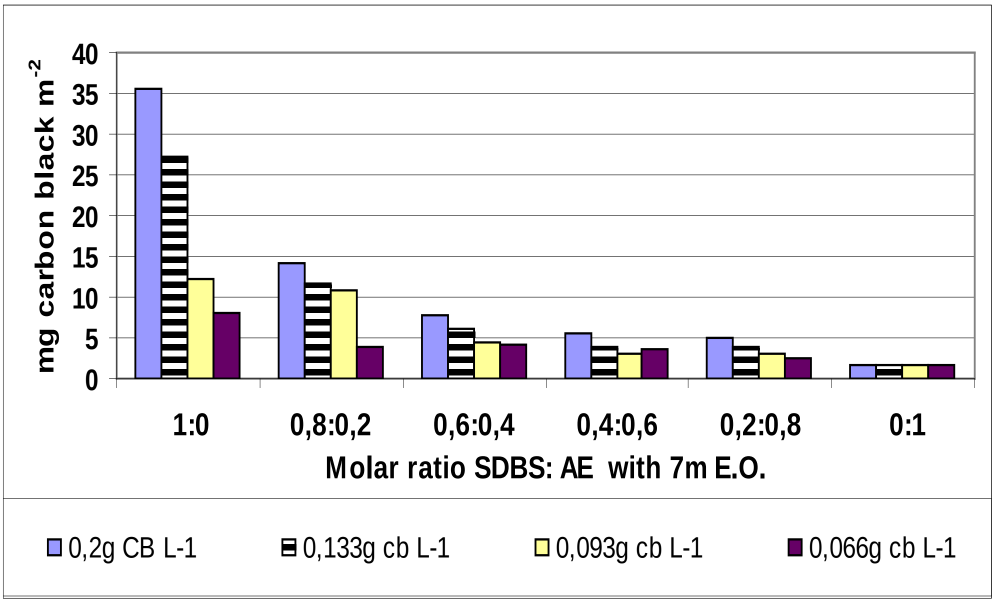

Figure 5. Amounts of carbon black deposited ($g.L^{-1}$) on acrylic fabric for different initial concentrations of carbon in the wash depending on proportions of mixture of the surfactants SDBS:AE with 7 m. E.O. at a total concentration of 5 $x10^{-3}$ M and

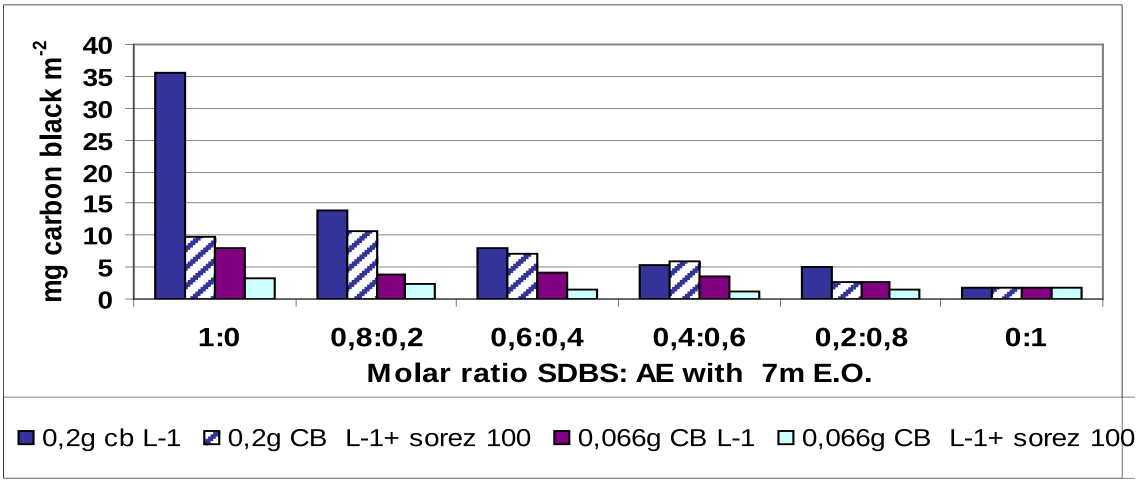

Figure 6. Amounts of carbon black deposited ($g.L^{-1}$) on acrylic fabric for different initial concentrations of carbon in the wash depending on proportions of mixture of the surfactants SDBS:AE with 7 m. E.O. at a total concentration of 5 $x10^{-3}$ M and with Sorez 100 at a concentration of 0.0725 $g.L^{-1}$ in the wash with carbon black from 0.0666 $g.L^{-1}$ to 0.2 $g.L^{-1}$

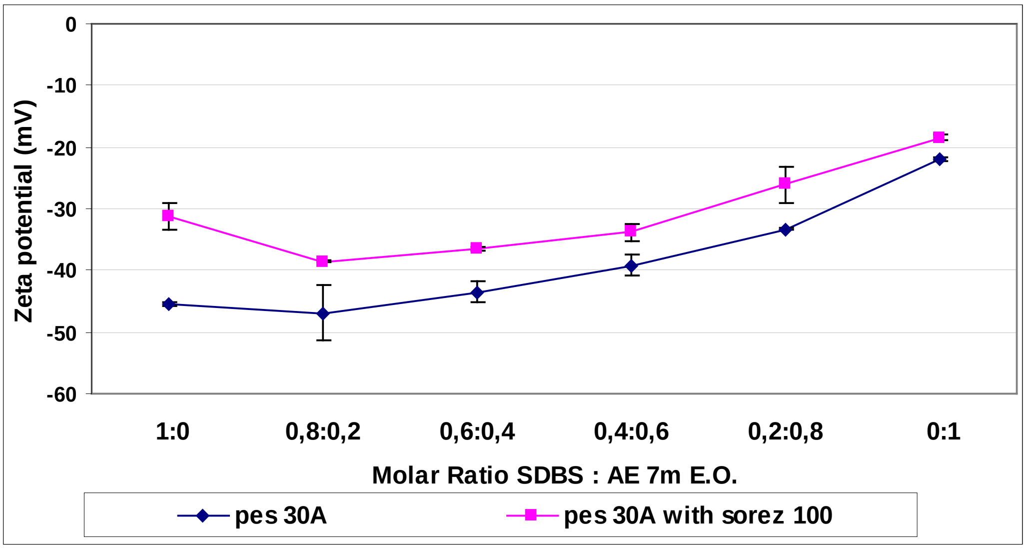

Figure 7. Zeta potentials of polyester fabric depending on the proportion of mixture of the surfactants SDBS:AE with 7 m. E.O. at a total concentration of 5 x10^{-3} M, with and without Sorez 100 at a concentration of 0.0725 g.L^{-1}, at pH 6 and temperature of 40ºC.

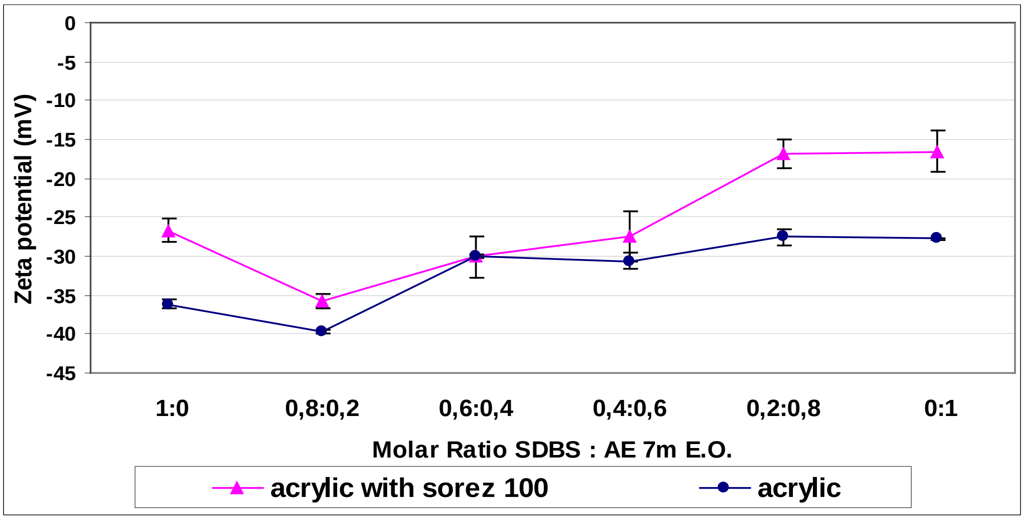

Figure 8 The same as the figure 5 for acrylic fabric

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