Influence of Amino-Functional Macro and Micro Silicone Softeners on the Properties of Cotton Fabric

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ABSTRACT

Amino-functional silicone softeners are most widely used type of soft finishes owing to their outstanding permanent softness, smoothness and handle characteristics. These soft finishes are prepared in different emulsion droplet sizes such as macro and micro emulsions providing varying characteristics on the textile on which they are applied. The macroemulsions due to their larger droplet sizes lubricate fabric and yarn surfaces, while the micro-emulsion, thanks to their smaller sizes penetrate inside fiber pores. In this research amino-functional macro and micro emulsions have been applied on dyed cotton fabric in 1:1 combination and compared against their influence on physical properties such as bending length, abrasion resistance, tensile strength, crease resistance and water repellency. These emulsions have also been compared for their influence on colorimetric properties; color difference and color strength (K/S values). The results reveal that the softener`s application in combination improves the properties deteriorated by each softener when applied separately.

Key Words: **Amino-Functional Macro and Micro, Silicone Softeners, Stiffness, Abrasion Resistance, Crease Resistance, Tensile Strength, Color Difference.**

1. INTRODUCTION

Finishing processes are performed at the end of textile production line which alter the structure of the textile with the aim to achieve desired characteristics in the fabric [1]. These finishing processes may be carried either by mechanical means or with the help of chemical finishing agents or combination of both.

Softeners are very important chemical finishing agents and play a significant role for suitability of a textile product for a particular application. Softening mechanism of softeners is based on reduction of the coefficient of friction between the fibers/yarns/filaments [2]. They provide soft hand and improve performance of the material in the upcoming production processes [3-4] such as sewing needle movement during garment manufacturing. Their application onto a textile substrate provides the same with soft hand, smoothness, flexibility, drape characteristics, increase crease resistance and antistatic properties. Textile fibers require softeners when either they inherently lack softness or their softness is lost during preparation/manufacturing processes [1,5-6]. The softeners have been classified into cationic, anionic, nonionic [3], amphoteric and silicone softeners based on their ionic nature [2,7-8].

Silicone softeners have surpassed other softeners in application due on one hand to excellent softness,

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improved hand feel and comfort properties when applied on various textile substrates [9-10] and on the other hand to their enhanced lubrication, mechanical and chemical stability [11] and translucent nature [5]. Due to excellent softness by these softeners, they are referred as super soft [1,10,12]. Generally, they produce improved crease resistance, pilling, protection against static charges, hydrophobicity, shrinkage and anti-foaming [10]. They are excellent surfactants and may reduce surface tension up to around 21mN/m [11].

Comparing with C-O-C bond, Si-O-Si possesses higher bond angles, longer bond lengths, free rotation of Si-O bond, free rotation of methyl groups and weak intermolecular forces of attraction [11]. Such chemistry of silicones makes them enable excellent softness and handle characteristics.

Modifications of silicone softeners such as amino, epoxy, amide, di-methyl, methyl-hydrogen, polyether and carboxyl silicones impart varying softness and fabric handle [1,12-15]. Among these softeners amino-functional silicones, which are positively charged, offer excellent softness and form durable films on the fabric surface, particularly negatively charged cotton (cellulosic) based textile substrates [1, 12, 13, 16] and are the most widely used silicones in textile industry [11, 13]. Amino-functional silicone softeners decrease co-efficient of friction between cellulosic textiles and reduce the gap between wool scales, thus produce a smoother surface [9,16].

Silicone softeners are prepared in the form of macro emulsions (particle size between 150-300nm), microemulsions (particle size < 40nm), semi-micro emulsions (particle size between 80-120nm) [17] and nanoemulsions (particle size <10nm) [18]. The particle sizes significantly affects penetration and distribution of silicones in the textile substrate. In case of macroemulsions silicones are deposited on the fabric and yarn surfaces, while microemulsions due to smaller particle sizes penetrate deeper and deposit silicones in the space between the fibers [1,10,17-18].

In this research aminofunctional silicone marcoemulsions and microemulsions have been combined together and applied on pure cotton fabric in order to evaluate their effects on the physical properties of the textile substrate.

2. MATERIALS AND METHOD

Pure cotton fabric (30x30/76x68) was dyed with 30 g/l of CI Reactive Black 5 (vinylsulphone). The dyeing was carried following pad-dry-cure method. Aminofunctional polysiloxane softeners, cationic, namely Solusoft WA liq (macroemulsion) and Solusoft MEJ (microemulsion), were applied in three concentrations, 10, 20 and 30 g/l on the dyed fabric. These macro and micro emulsions were later combined in 1:1 combination, i.e. for 10g/l solutions 5 g/l of macro emulsion and 5 g/l of micro emulsion were mixed together. These finishes were applied through pad-dry method using laboratory scale horizontal padder (pick-up: 75% and rpm: 5).

Fabric stiffness was measured in terms of bending length (cm) using the Shirley Stiffness Tester and following test method ASTM-D1388-96 R02. For abrasion resistance, the fabric samples were tested using Martindale Abrasion and Pilling Tester M227, following ASTM D-4966 (Option 3, mass loss %age); treatment cycles: 9000 cycles under 9±2 kpa load. Crease resistance was determined in terms of wrinkle recovery angle following standard method AATCC-66. Tensile strength tests were performed on Uster Tensorapid 4 following ASTM D5035 test method. Standard test method AATCC 79 was followed for water absorbency; time (in seconds) taken by specular reflection of water drop to disappear from the surface of the fabric was recorded after it was dropped on the same from a fixed height.

Colorimetric tests were performed on X-Rite Color Eye 7000A Spectrophotometer (using D65 illuminant). CIE color difference Equation (1) and color strength Equation (2) used are given below. For color difference standard was dyed fabric without any silicone softener.

$$\Delta E(CMC) = \sqrt{\left(\frac{\Delta L}{lSL}\right)^2 + \left(\frac{\Delta C}{cSc}\right)^2 + \left(\frac{\Delta H}{SH}\right)^2} \quad (1)$$

$$\frac{K}{S} = \frac{(1 - R\%)^2}{2R} \quad (2)$$

Colorfastness to washing was determined by following ISO-105 CO3 method.

3. RESULTS AND DISCUSSION

3.1 Fabric Stiffness

Results, for fabric stiffness, reported in Fig. 1 show silicone microemulsions producing low drape lengths than the macroemulsions, while, the combined application of these emulsions shows even better softness; stiffer fabrics enable higher bending length values. This is due to the lubrication of yarns surfaces by macroemulsions and inner penetration of microemulsions and lubrication of fibers [1,17]. The improved results from combinations may be due to softener's film formation on fibers, and at the yarn and fabric surface, making fabric less stiff.

3.2 Abrasion Resistance

Fabric abrasion resistance plays significant role on the life of a textile material and its resistance to changes when abraded against other surfaces. Results reported in Fig. 2 show that the microemulsions increase mass loss %age as compared with the macroemulsions while their combined application reduces this behavior of microemulsions. Reduced abrasion resistance is the result of minimization of the co-efficient of friction by these softeners [9,16].

3.3 Crease Resistance

Crease formation is an inherent property of cotton [17,19], which is a very important fiber used to manufacture versatile product and satisfies about 50 % of world fiber consumption [20]. Many of the applications for cotton fabric requires it to be wrinkle free or to have lower creasing properties. Influence of the silicone macroemulsion and microemulsions have been evaluated and the results are reported in Fig. 3. It is observed that the microemulsions incorporate higher crease recovery properties to the textiles than the macro emulsions and combination of micro and macro emulsions show recovery values in between.

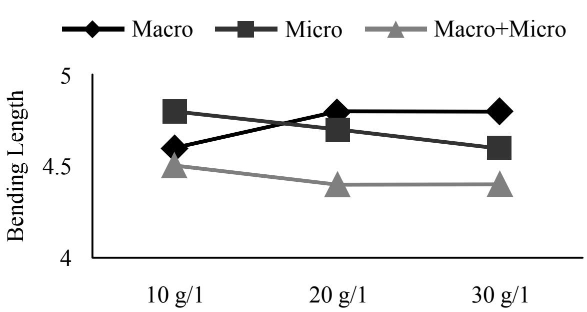

FIG. 1. FABRIC STIFFNESS (BENDING LENGTH IN cm)

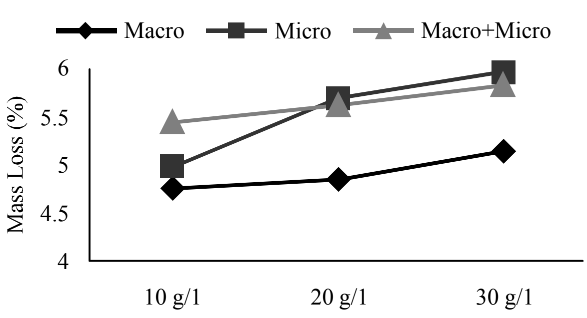

FIG. 2. ABRASION RESISTANCE RESULTS (MASS LOSS %)

3.4 Tensile Strength

The results for tensile strength of cotton fabric, expressed in cN (centi Newtons) are reported in Fig. 4. The results reveal that microemulsions, due to smaller particle of silicones, lubrication of fiber and the reduction of the coefficient of friction between the fibers, reduce the tensile strength of the fabric samples more than macroemulsions, [21] while combined application of micro and macro emulsions is observed to slightly improve this behavior of silicone microemulsions.

3.5 Water Absorbency

Silicone softeners have significant influence on the water repellency of the cotton fabric. The results reported in Fig. 5 show macroemulsion producing significantly higher water repellency than the silicone microemulsions. Water repellency by the silicone softeners is due to the methyl groups [1]. Water absorption time for macroemulsions was observed to be substantially higher than the microemulsions.

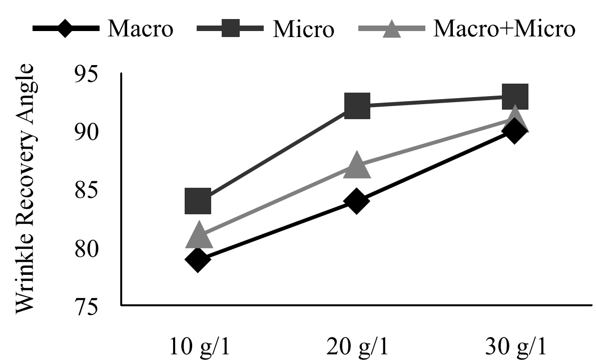

FIG. 3 CREASE RESISTANCE OF THE TREATED SAMPLES

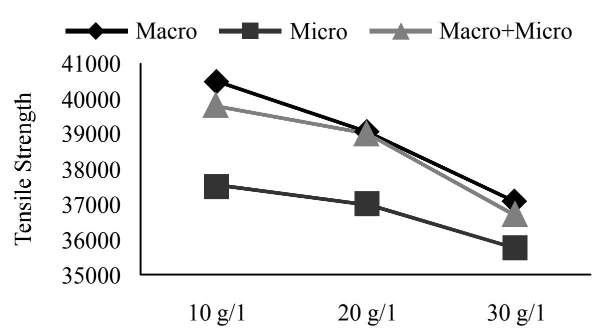

FIG. 4 TENSILE STRENGTH OF COTTON FABRIC SAMPLES (cN)

3.6 Color Difference

Influence of amino-functional silicone softeners on color difference and color strength (K/S) values is given in the Table 1. It can be observed that the macroemulsions have higher increase of color difference and higher K/S values than the microemulsions. Application in combination shows little influence on color difference except for 30g/l concentration. Silicone's characteristic of having lower refractive index than cotton [17,19] influences its colorimetric properties and dyed fabric treated with silicones have darker appearance [17]. Washing fastness results have been observed to be consistent presenting no significant variation for single washing.

The aminofunctional silicone macroemulsions due to larger silicone particle size [17] contributes to make the shade to appear darker than the aminofunctional silicone microemulsions. The microemulsions due to smaller silicone particle size and also due to higher content of emulsifier [17], show little influence on the dyed cotton fabric.

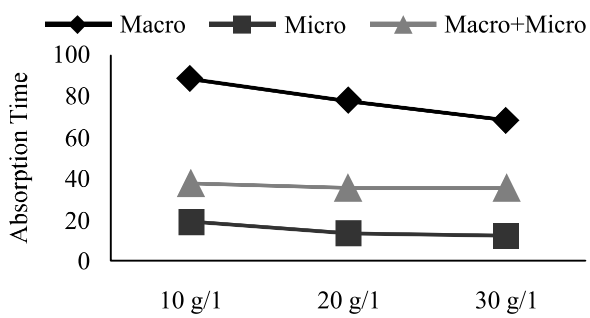

FIG. 5 WATER ABSORPTION TIME [SECONDS]

TABLE 1. COLOR DIFFERENCE, COLOR STRENGTH (K/S VALUES) AND WASHING FASTNESS RESULTS

Softener	Concentration (g/l)	Color Difference (ΔE)	Color Strength (K/S Value)	Washing Fastness (Shade Change)
Macro	10	1.49	21.86	4.5
	20	1.07	22.48	4.5
	30	1.35	23.76	4.5
Micro	10	0.70	20.38	4.5
	20	0.72	21.43	4.5
	30	0.92	22.71	4.5
Macro+Micro	10	0.35	20.85	4.5
	20	0.39	21.33	4.5
	30	1.30	23.76	4.5

4. CONCLUSION

Amino-functional macro and micro silicone emulsions, due to different silicone particle sizes, have varying effect on physical properties of pure cotton fabric. Microemulsions produce comparatively higher reduction of stiffness, tensile strength and water repellency and increase crease resistance of cotton fabric. While, the aminofunctional silicone macroemulsions are observed to show greater increase of color difference and higher color strength (K/S values). Combination of macro and micro emulsions can compensate the negative influence of the other when required for certain applications of cotton fabric.

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