

Process Intensification of Simultaneous Direct Dyeing and Resin Finishing of Cotton Fabrics

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Abstract: The necessity to meet the growing demand of consumers led to the evolution in functional finishes in textile industry. Textiles should satisfy the functional, comfort, aesthetic, and ecological requirements. Cotton is one of the most commonly used fibres for textiles, as many garments are made from dyed and finished cotton. Conventionally, cotton is dyed first, and then finished with a crosslinking agent to obtain the desired colour and wrinkle resistant properties. If the two steps could be merged, significant savings in energy, chemicals, water, labour, and time would be achieved. Many researchers have attempted to combine dyeing and finishing processes into one step although many such attempts face problem on their commercial viability. The main challenge of this one step process is the problem of producing the treated fabrics with required deep shades, good wash fastness, and crease recovery angle (CRA) without affecting the tensile strength of the fabric adversely. In this work, simultaneous direct dyeing and resin finishing was carried out to explore the potential of reduction in energy consumption, time of production as well as dyes and chemicals. The work was done by varying the concentration of low formaldehyde based DMDHEU and direct dyes. Evaluations of the simultaneously dyed and finished (SDF) fabrics were made with respect to colour strength (K/S), crease recovery angle (CRA), tensile strength, weight add-on and fastness properties, and the findings were compared with those of control samples. The results showed good CRA value, a high improvement in the surface colour strength and washing fastness compared to that of ordinary cotton fabric when separately dyed with direct dye.

KEYWORDS: Cotton fabric, Direct Dye, Low Formaldehyde DMDHEU, Crease Recovery, K/S, Wash Fastness

I. INTRODUCTION

The textile industry is one of the oldest and most technologically complex of all the industries. With increasing demand of textile materials due to population growth and increasing environmental issues, textile industries are facing challenges to exist as sustainable industries. Now days it is mandatory for textile industries to follow sustainable production for competing in quality, productivity and price while addressing environmental issues. The textile industry ranks among the top energy users. About 60% of the total energy consumed in textile mills is used in wet processing only, so it is timely to think of processes which would result in lowering of energy consumption leading to sustainable development. By taking this into consideration, the textile manufactures and researchers have been trying to lower the energy consumption by modifying, shortening, and combining various processes [1].

One of the major drawbacks of cotton fibre is its poor crease recovery property which can be improved by crosslinking of hydroxyl groups with suitable finishing agent [2]. Various kinds of resins have been developed from time to time to improve wrinkle resistance of cotton fabrics, but most of them are based on formaldehyde. Among all the conventional resins used nowadays, DMDHEU is commercially widely accepted in industry due to its good crease

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recovery angle, cost effectiveness and easy availability. However, the trend is towards use of low formaldehyde based DMDHEU [3].

Direct dye is a class of dyestuffs which is anionic in nature and has substantivity for cellulosic fibres and applied directly to the substrate in a neutral or alkaline bath [4]. They produce full shades on cotton and linen without mordant and can also be applied to rayon, silk, and wool. Direct dyes give bright shades, but exhibit poor wash fastness. Various after treatments are used to improve the wash fastness of direct dyes. Direct dye molecules adhere to the fabric molecules without forming any permanent chemical bond with the cellulosic fibres, but are attached to it via very weak hydrogen bonds as well as Vander Waals forces. Their flat shape and linearity enable them to align themselves along cellulose fibres and maximize the Van-der-Waals forces, and hydrogen bonds

The usual procedure for dyeing and resin finishing of fabrics involves the application of the two processes separately and in succession i.e. the fabric is first dyed and then finished. Many attempts for application of both treatments in a single operation to save energy and cost were reported by different scholars [5-18] and this work of simultaneous dyeing and finishing is an attempt in this direction of saving energy, cost and time. In present study, direct dyes along with low formaldehyde DMDHEU using ammonium sulphate as catalyst have been used for simultaneous direct dyeing and modified DMDHEU finishing of cotton fabric and some parameters were varied and their influence on the finished fabric was studied in terms of colour strength (K/S values), crease recovery angle, tensile strength, add-on and washing fastness. The results of this study have been presented in this paper.

II. MATERIALS AND METHODS

II.I. Materials

Fabric: The ready for dyeing (RFD) cotton fabric (100 GSM) was supplied by PiyushSindycate, Mumbai.

Dyes: Dyes used were Tuladir Blue SF (C.I Direct Blue 71) with molecular weight of 1029.86 g/mol and Atul Direct Sun Yellow RCH (C.I Direct Yellow 99) with molecular weight of 624.55 g/mol which were supplied by Atul Chemicals Limited, India.

Chemicals: Cresotex ULFC (low formaldehyde DMDHEU) was supplied by Associated Chemicals. Sodium carbonate and acetic acid of laboratory grade were supplied by SDFine Chemicals, Mumbai and non-ionic detergent, Auxipon NP, was supplied by Auxichem Private Limited, Mumbai.

II.II. Methods

The work done includes processes like pre-treatment of the fabric, padding process for dyeing of control fabrics and simultaneous dyeing and finishing. The details were described below.

Pre-treatment: The cotton fabric was washed with 5g/l sodium carbonate (Na_2CO_3) using a material to liquor ratio (MLR) of 1:50. The process was carried out at boil for 45 min. Fabric was then washed with hot and cold water to make it free from alkali.

Preparation of control fabrics: Pre-treated cotton fabric was padded through the bath containing only dye solution at room temperature (RT) using a laboratory padding mangle by two-dip and two-nip process at a pressure of 4kg/cm^2 to obtain 70% wet pick-up. After padding, the fabric was dried in laboratory mini dryer at 80°C for 5 min and cured at 150°C for 3 min using laboratory stenter. Then, the fabric was soaped, washed and dried.

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Simultaneous direct dyeing and resin finishing: Samples to be treated were padded through the bath containing varying concentrations of dye and low formaldehyde based DMDHEU. For formulation of the padding solution, low formaldehyde DMDHEU (Creasotex ULFC) was used with C.I Direct Blue 71 and C.I Direct Yellow 99 dyes. The catalyst concentration used was 10% of the concentration of low formaldehyde DMDHEU. Then the padded samples were dried at 80°C for 5 min and then cured at 150°C for 3 minutes using stenter. Finally the treated samples were washed off with solution containing 5g/l non-ionic surfactant at 50°C for 20 min, then washed with fresh water and dried.

Determination of Add-on, (%): Samples were weighed on weighing balance before and after the simultaneous dyeing and resin finishing. Samples were dried in the oven and conditioned in desiccator for 24 hours before reweighing. Add-on, (%) was then calculated using formula;

$$\text{Add-on, (\%)} = \left[\frac{(B - A)}{A} \right] * 100$$

where, A is weight of samples in grams before treatment and B is weight of samples in grams after simultaneous dyeing and finishing.

Determination of Colour Strength: The dyed samples were evaluated for the depth of colour by reflectance method using 10 degree observer. The absorbance of the dyed samples was measured on Rayscan Spectra scan 5100+ equipped with reflectance accessories. The KubelkaMunk function or K/S values were determined using expression;

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

where K is the absorption coefficient; S is scattering coefficient; and R is reflectance of the dyed fabric at the wavelength of maximum absorption.

Determination of Washing Fastness: Dyed fabrics were tested for colour fastness to washing according to ISO 105:C02 test method. Solution containing 5 g/l non-ionic surfactant was used as wash liquor. The samples were treated for 45 min at 50°C using material to liquor ratio of 1:50 in Rotamachine. After rinsing and drying, the change in colour of the samples was evaluated on the respective standard scales (rating 1-5, where 1-poor, 2-fair, 3-good, 4-very good and 5-excellent).

Determination of Crease Recovery Angle (CRA): To estimate the wrinkle resistance of the finished fabric, its crease recovery angle was measured using Shirley's crease recovery tester by ASTM D-1296 method (ASTM standards manual). Change in CRA (%) was calculated using equation;

$$\text{Increase in CRA, (\%)} = \left[\frac{(B - A)}{A} \right] * 100$$

where, A and B are CRA readings of untreated and treated samples, respectively.

Determination of loss in Tensile strength, (%): Tensile strength of finished fabric was evaluated using ASTM D-5035, raveled strip Test method (ASTM standards manual). Loss in tensile strength, (%) was calculated using formula;

$$\text{Loss in tensile strength, (\%)} = \left[\frac{(A - B)}{A} \right] * 100$$

where, A and B are breaking strength readings of untreated and treated samples respectively.

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III. RESULTS AND DISCUSSION

Fabric samples were padded through the bath containing dye (10g/l and 20g/l) and low formaldehyde DMDHEU (90gpl, 120gpl, 150gpl) with 10% catalyst on the basis of resin concentration. Pad-dry-cure method was used as described in experimental and the results obtained are summarized and discussed below.

III.I. Effect of Resin (Creasotex ULFC) Concentration on CRA Properties of SDF Fabric

The crosslinking resin (Creasotex ULFC), a low formaldehydedimethyloldihydroxy-ethyleneurea (DMDHEU), cross-links with fibre and these results in increased wrinkle-resistance, dimensional stability and shape retention.

Table 1. CRA Values for SDF Fabric with C.I Direct Blue 71 and C.I Direct Yellow 99

Resin concentration, (gpl)	Dye concentration, (gpl)	Total CRA (°)		Increase in CRA over RFD Fabric, (%)	
		C.I. Direct Blue 71	C.I. Direct Yellow 99	C.I. Direct Blue 71	C.I. Direct Yellow 99
0	10	125	125	0.0	0.0
0	10	132	133	5.6	6.4
90	10	183	191	46.4	52.8
120	10	200	192.5	60.0	54.0
150	10	208	207	66.4	65.6
90	20	190	184	52.0	47.2
120	20	201	197	60.8	57.6
150	20	216	208	72.8	66.4

Results in the Table 1 and Fig. 1 indicate that CRA of the treated samples increased with increasing concentrations of Creasotex ULFC. The Creasotex ULFC cross-links with fibre and this result in increased wrinkle-resistance, dimensional stability and shape retention. Due to crosslinking of resin with –OH groups of intra and inter molecular cellulosic chains, the cotton fabric develops the increased property of recovery from creases. This is also due to decreased tendency of hydrogen bonding among relatively less number of –OH groups available.

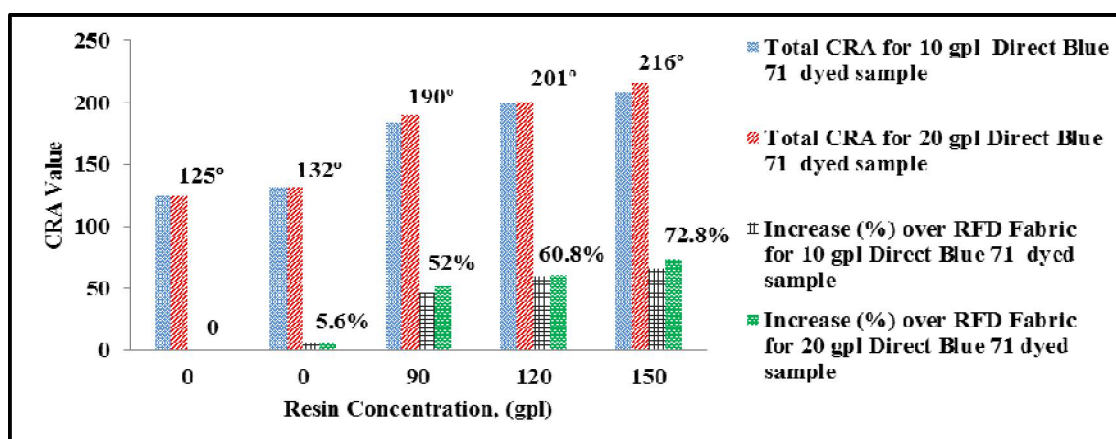


Figure 1. Effect of Creasotex ULFC on CRA Values of SDF sample with C.I Direct Blue 71

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The Fig.1 shows that as the concentration of resin increased, the CRA of of SDF fabric sample also increasend.The maximum CRA value obtained was around **216°** and percent increase in CRA value over that of RFD fabric was around **72.8**.

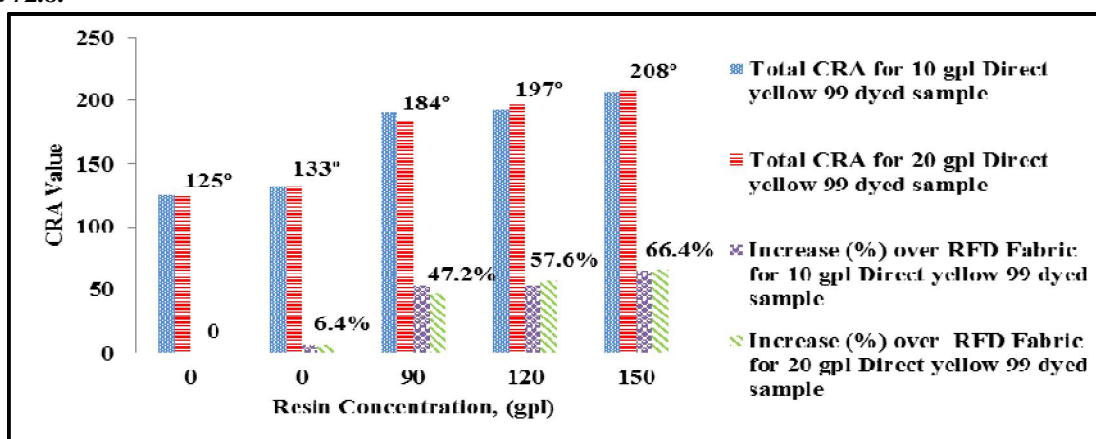


Figure 2. Effect of Creasotex ULFC on CRA Value of SDF sample with C.I. Direct yellow 99.

The results in Table 1 and Fig. 2 shows that as the concentration of Creasotex ULFC increased, the CRA of Creasotex ULFC treated sample also increasend. The maximum CRA obtained for the simultaneously dyed sample with C.I Direct yellow 99 and finished with Creasotex ULFC was around **208°** and the percent increase in CRA value over RFD fabric was around **66.4**. Increase in CRA as a result of increase in concentration of resin indicates higher extent of crosslinking between cellulose polymer chains because of increased concentrations of multifunctional resin.

The results from Table 1 showed that the CRA values for C.I Direct Blue 71 were slightly higher than C.I Direct Yellow 99. This may be related to the molecular weight of the dyes used. As mentioned earlier the molecular weight of C.I Direct Blue 71 and C.I Direct Yellow 99 were 1029.86 and 624.55 g/mol, respectively. This smaller size of the yellow dye molecules may lead to its better penetration and must have resulted in good diffusion of the dyes into the fibre interior. This leads to the increased amount of resin reacted with dye which finally resulted in better colour strength of the SDF samples at the expense of CRA value. However the blue dye gave slightly higher CRA value due to its bigger molecular size and this high molecular weight leads to poor migration and diffusion of the dye into the fibre which resulted in the less amount of resin reacting with the dye making it available for crosslinking with the fibre and thus which finally improving the CRA values of the SF fabric. Moreover, simultaneous dyeing and finishing might occurs due to the reaction of the dye with the cotton fabric through a crosslinking agent. This reaction of resin with the fibre on one side and the dye on the other side resulted in relatively less CRA value compared to the sample treated with resin and catalyst without dyestuff. This is because of less extent of the crosslinking of the resin taking place with fibre as some of it is spent on reacting with the dye as mentioned in our earlier work [1, 2].

III.II. Effect of Resin (Creasotex ULFC) on K/S Values of SDF Fabric

The K/S value is one of the key values in reflecting the surface colour strength of the dyed products. The colour strength (K/S) depends on the nature of the dye, i.e. the molecular size, configuration, reactive groups and solubility and their tinctorial properties. Direct dyes are adhered to cellulosic fibre via physical bonds like Van der Waals forces and hydrogen bonding. This poor physical bonds lead to easy removal of colour during washing. This poor wash fastness property of the direct dyed material directly affects the surface colour strength.

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Table 2. K/S value for SDF Fabric with C.I. Direct Blue 71 and C.I. Direct Yellow 99

Resin concentration, n, (gpl)	Dye concentration, (gpl)	K/S Value		Increase in K/S, (%) over padded fabric w/o resin	
		C.I. Direct Blue 71	C.I. Direct Yellow 99	C.I. Direct Blue 71	C.I. Direct Yellow 99
0	10	0.00	0.00	-	-
0	10	6.37	7.50	0.00	0.00
90	10	9.67	11.37	51.80	51.60
120	10	10.50	12.62	64.80	67.07
150	10	11.05	12.78	73.50	70.40
90	20	9.84	11.60	54.47	54.67
120	20	10.65	12.53	67.19	68.27
150	20	11.50	12.89	80.53	71.87

Results from the Table 2, Fig. 3 and Fig. 4 reveal that as the concentration of resin increased the K/S values of the treated samples increased significantly for both C.I Direct Blue 71 and C.I Direct yellow 99 and the samples treated using highest concentration of resin gave very high increase in K/S (%) over that of padded fabric without resin. With increase in the concentration of the resin, increased amounts of dye were getting fixed. This is because the crosslinking sites of the resin react with dye on one hand and the other side reacts with the fabric. Samples treated with resin and catalyst without dye, showed no coloration, but CRA values of these samples were higher as compared to those of SDF fabric. In this case, addition of dye, catalyst and crosslinking agent to the pad bath together showed successful achievement of simultaneous dyeing and finishing with high surface colour strength and CRA values.

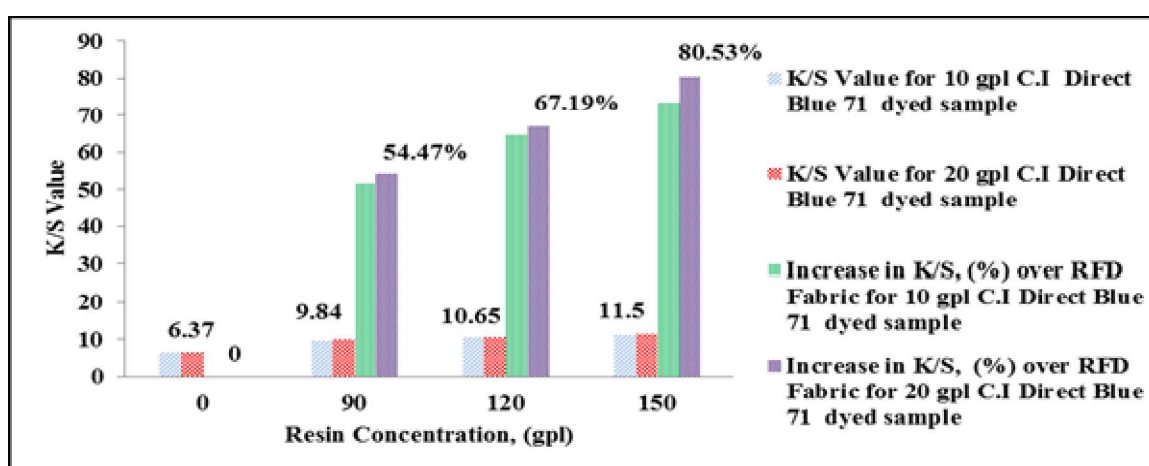


Figure 3. Effect of Creasotex ULFC on K/S Values of SDF Sample with C.I. Direct Blue 71.

The Fig. 3 reveals that the sample treated using highest concentration of resin gave very high increase in K/S value of C.I Direct Blue i.e. **80%** over that of the samples padded without resin. Similarly results in Fig. 4, further support this behavior for C.I Direct Yellow 99 in which case maximum increase in K/S value was **71.87%** for highest

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concentration of resin. This considerable increase in K/S was due to the fixation of some dyes taking place by the covalent bonds between the nucleophilic groups of the dyestuffs (-NH₂, -OH, -NH) and the fibre.

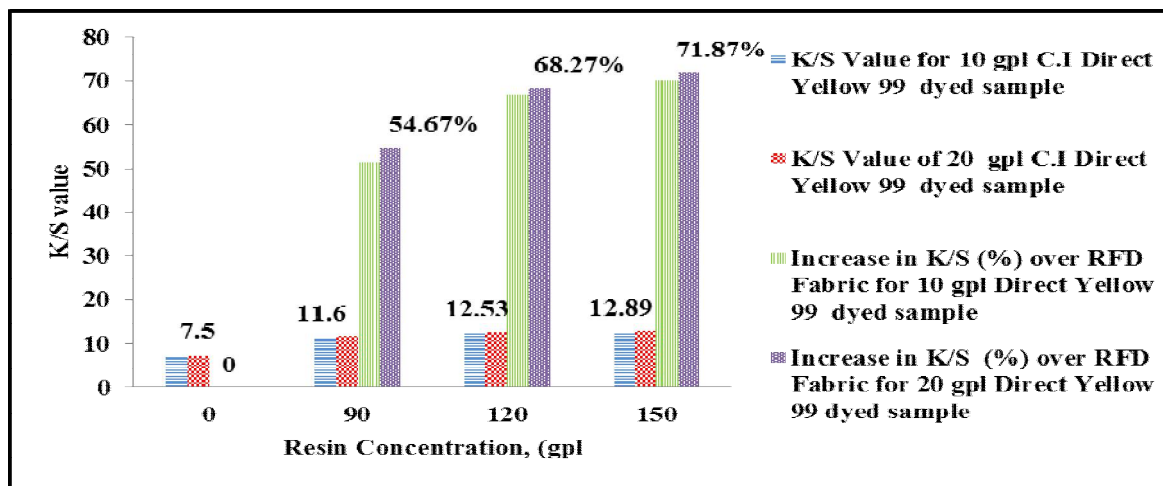


Figure 4. Effect of Creasotex ULFC on K/S Value of SDF sample with C.I. Direct Yellow 99.

From the Figures 3 and 4, it is seen that the K/S value for the C.I. Direct Yellow dye was slightly higher than that of C.I. Direct Blue dye. Which means that, the yellow dye imparted good colour strength in SDF process when compared with that of the blue dye. This may be due to the smaller size of the yellow dye molecules which leads to its better penetration and hence gave better K/S value than that of blue dye with big molecular size. Also individual dyes have different tinctorial power too which affects K/S values.

III.III. Effect of Resin (Creasotex ULFC) on Tensile Strength of SDF Fabric

Table 3. Breaking Strength value for SDF Fabric with C.I. Direct Blue 71 and Direct Yellow 99

Resin concentration, (gpl)	Dye concentration, (gpl)	Breaking strength, (kgf)		Tensile Strength loss, (%)	
		C.I. Direct Blue 71	C.I. Direct Yellow 99	C.I. Direct Blue 71	C.I. Direct Yellow 99
0	0	28.76	28.76	0	0
0	10	28.25	27.87	1.77	3.09
90	10	25.95	25.09	9.77	12.76
120	10	23.12	24.47	19.61	14.92
150	10	21.68	22.68	24.62	21.14
90	20	25.25	25.48	12.20	11.40
120	20	22.84	23.75	20.58	17.42
150	20	21.55	22.12	25.07	23.09

Results in the Table 3 indicate that breaking strength value for both simultaneously dyed and finished fabric with C.I. Direct Blue 71 and C.I. Direct yellow 99 using Creasotex ULFC decreased with the increase in the concentration of resin. This is attributed by the increased crosslinking between the fibre and the resin in the cellulosic polymers

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which creates in the fibre more weak spots and rigidity. The samples treated using highest concentration of modified DMDHEU gave very high percent loss in tensile strength over untreated ones.

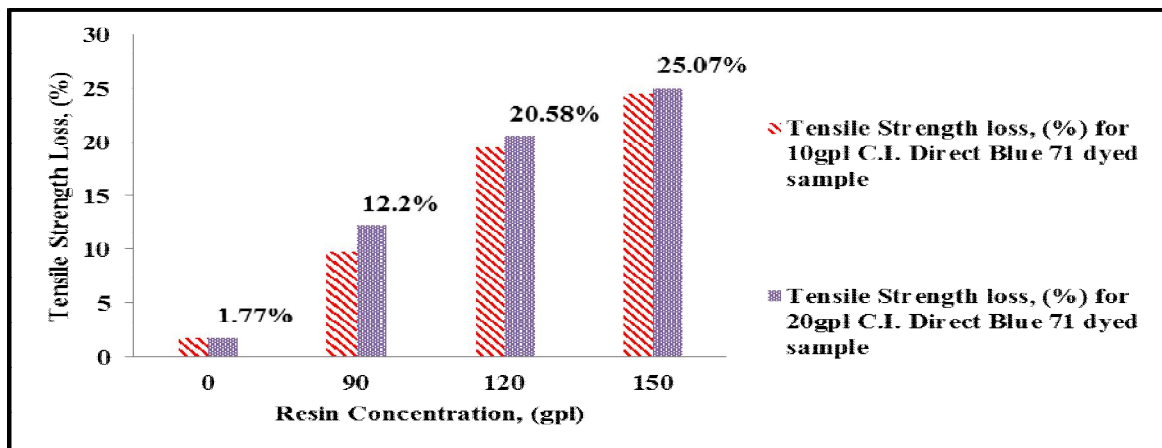


Figure 5. Effect of Creasotex ULF on Tensile strength loss of SDF sample with C.I. Direct Blue 71

The Fig.5 shows that, the sample treated using highest concentration of resin made the fabric weaker and gave relatively high percent loss i.e. **25%** over that untreated ones. The Fig. 6 shows the similar trend for reduction in tensile strength with increase in resin concentration for C.I. Direct yellow 99 dye and Creasotex ULFC resin.

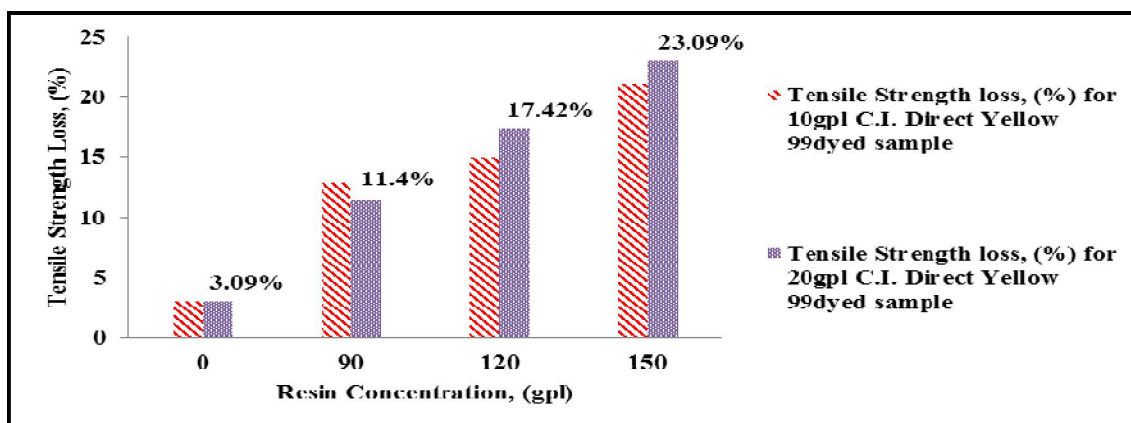


Figure 6. Effect of Creasotex ULFC on Tensile Strength loss of SDF sample with C.I. Direct Yellow 99.

The loss in tensile strength was due to the increased crosslinking between the cellulosic polymer and the resin, creating weak spots and very poor load distribution among the polymeric chains. The crosslinks that are formed with the resin obviously prevent the redistribution of stress by preventing movement within the fibre microstructure. The crosslinking of cellulose molecules with resins like DMDHEU causes stiffening of the cellulosic macromolecular network and make the fibre weaker, thus dropping the mechanical strength of the treated cotton fabrics. In general, the decrease in tensile strength is mainly attributed to the increase in crosslinking between the cellulose polymer chain molecules, as reflected in CRA properties. The extent of cross linking increases rigidity of the polymer chain and ability to share the stress commensurately is decreased. This makes the polymer slightly rigid and brittle. Also, at the points of crosslinking, weak spots in polymer chains are created which cause the chain cleavage at the

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lower loads. It is also possible that certain amount or even slight excess of ammonium sulphate catalyst on decomposition at curing temperature may cause cellulose chain degradation due to the acids liberated at the temperature of curing. This may also responsible for reducing the tensile strength of cotton fabric. So, the magnitude of fabric strength loss can be affected by the temperature of curing, curing period, and concentration of the catalyst in addition to concentration of resin.

III.IV. Effect of Resin (Creasotex ULFC) on Weight Add-On Properties of SDF Fabric

Table 4. Weight Add-on % value for SDF Fabric with C.I Direct Blue 71 and C.I Direct Yellow 99

Resin concentration, (gpl)	Dye concentration, (gpl)	Weight Add-on, (%)	
		C.I. Direct Blue 71	C.I. Direct Yellow 99
90	10	3.10	3.33
120	10	3.49	3.65
150	10	3.56	3.72
90	20	3.23	3.36
120	20	3.57	3.72
150	20	3.58	3.75

Results in Table 4 indicate that the weight add-on increased with the increase in concentration of the resin. This is attributed to increased amounts of resin and dye deposition on the fabric. Increase in add-on is due to increased amounts of resin being cross-linked with the treated samples at higher concentration of resin.

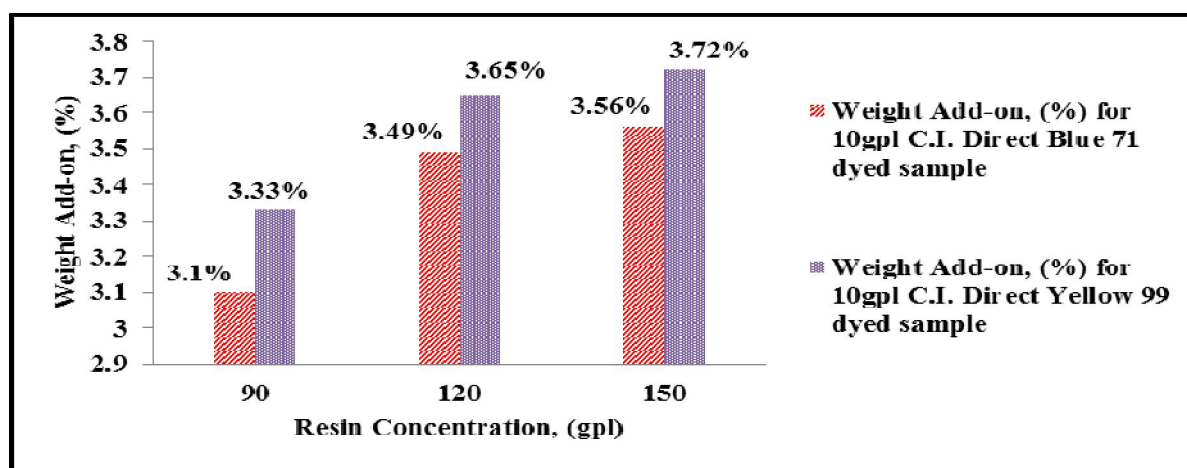


Figure 7. Effect of CreasotexULFC on Weight Add-On of SDF sample with 10 gpl of C.I. Direct Blue 71 and C.I. Direct Yellow 99.

Results in Fig. 7 and 8 indicate that the weight add-on increased with the increase in concentration of the resin and dyes. This is attributed to increased amounts of resin and dye deposition on the fabric. Increase in add-on is due to increased amounts of resin being cross-linked with the treated samples at higher concentration of resin. An increased amount of resin is also responsible to take up more amounts of dye molecules which get anchored with the fibre polymer. Although technically dye is also getting increasingly fixed, the contribution of dye in overall weight of the

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fabric being negligible, it is assumed that increase in weight gain of resin finished and dyed fabric is due to increase in mainly the resin fixation.

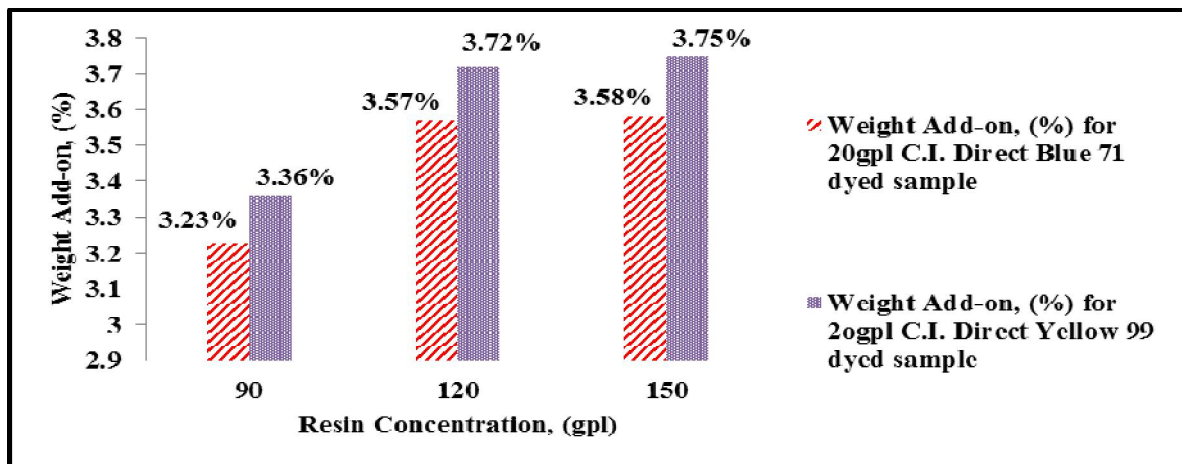


Figure 8. Effect of CreasotexULFC on Weight Add-On of SDF sample with 20 gpl of C.I. Direct Blue 71 and C.I. Direct Yellow 99.

The Fig.7 and 8 show there existed positive dependence of weight add-on on the resin. However the weight add-on in C.I Direct yellow 99 was slightly higher that that of C.I Direct Blue 71, which may be attributed to the increased extent of crosslinking of resin and fixation as well as that of deposition of the dyes inside the fibre due to the increased crosslinking between the dye and the resin in the fibre.

III.V. Effect of Resin (Creasotex ULFC) on Washing Fastness Properties of SDF Fabric

Table 5.ISO 105:C02 washing fastness results of SDF fabric with C.I. Direct Blue 71and C.I Direct Yellow 99

Resin concentration, (gpl)	Dye concentration, (gpl)	Wash Fastness	
		C.I. Direct Blue 71	C.I. Direct Yellow 99
0	10	2-3	2-3
90	10	4-5	4-5
120	10	4-5	4-5
150	10	4-5	4-5
90	20	2-3	2-3
120	20	4-5	4-5
150	20	4-5	4-5

ISO 105:C02 Washing fastness ratings show that the SDF fabric exhibited very good fastness properties. Direct dyes have affinity for the cellulosic fibres due to their planar/flat structures. However, in the above simultaneous dyeing and finishing process, as the concentration of resin increased, dye fixation also increased. Results from the Table 5 indicate that as the concentration of the resin increased, it exhibited positive effect on the amount of dye cross-linked with the fibre polymer which in turn improves the fastness properties of the dyed fabric. Generally it was observed that for low concentration of resin, the wash fastness was less, but as the concentration of resin increased, the fastness to washing was more than 4. This was very good for direct dyed fabric and it is impossible to get such high level of fastness in

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conventional direct dyeing, without making any after treatment. These high fastness ratings indicate that the dye was fixed with the fibre through bonds other than physical bonds like Van der Waals forces and hydrogen bonding. Therefore it was expected that the dye might be reacted with the fibre through covalent bonding. Earlier research work on this mechanism of dye getting fixed on fabric by covalent bonding through resin has been already reported [2].

Table 6. The effect of curing temperature and period of curing on SDF fabric with C.I. Direct Blue 71 and C.I. Direct Yellow 99

Temperature (°C)	Period of curing (minute)	K/S Value		CRA Value, (°)		Tensile strength Loss, (%)	
		C.I. Direct Blue 71	C.I. Direct Yellow 99	C.I. Direct Blue 71	C.I. Direct Yellow 99	C.I. Direct Blue 71	C.I. Direct Yellow 99
170	3	12.28	15.80	230	224	31.95	32.19
150	5	11.70	13.15	210	207	26.98	24.13
150	3	10.50	12.62	200	192.5	19.61	14.92
150	1	8.09	9.60	181	180	16.93	14.36
120	3	8.16	8.90	160	170	10.15	9.11

III.VI. Effect of curing Temperature on Properties of SDF Fabric

Results in Table 6 showed that the effect of curing temperature (120, 150 and 170°C) on the properties of simultaneously dyed with dyes (C.I. direct blue 71 and C.I. direct yellow 99, 10gpl) and finished with 120gpl of Creasotex ULFC and 12gpl of catalyst concentration. It was observed that as curing temperature increased there was high increase in K/S, CRA value and tensile strength loss. This might be due to the increased decomposition of the catalyst (ammonium sulphate) at high temperature and liberating the acid which in turn responsible for facilitation of the reaction between the fibre and the resin on one hand and dye and resin on the other. Hence K/S and CRA values also increased although consequent strength loss was observed as discussed earlier.

III.VII. Effect of curing Period on Properties of SDF Fabric

Table 6 also showed the effect of curing period on the properties of SDF fabric when catalyst concentration of 12gpl and curing temperature of 150°C were used. It was observed that the increase in curing period from 1 min to 5 min resulted in increase in K/S, CRA and loss in tensile strength values. This increase in aforementioned properties might be attributed to the increased decomposition of the catalyst (ammonium sulphate) at longer curing period causing increased liberation of the acid which in turn was responsible for assisting of the reaction between the fibre and the resin giving the improved K/S and CRA values. Although consequent to increased crosslinking, the strength loss as discussed earlier, was obviously expected.

IV. CONCLUSION

The objectives of this study was to examine the results of combined direct dyeing and resin finishing with those of conventional direct dyeing and resin finishing of cotton fabrics which basically needs two baths of separate processing for dyeing and finishing. It was revealed that the K/S values of the SDF treated samples increased significantly for both C.I. Direct Blue 71 and C.I. Direct yellow 99 and they gave very high increase in K/S (%) over that of conventionally padded fabric. Moreover, it was further observed that the CRA values of various SDF samples were found to be more than 200° which can be rated as good for production of wrinkle free cotton fabric. The ISO II wash fastness was found to be of grade 4 i.e. very good. Of course there was loss in tensile strength up to 25%, which was inevitable. However,

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this could be reduced by choosing the correct resin concentration which can give comparable results with reduced tensile strength loss. In this work, it was observed that the samples treated with resin concentration of 120gpl gave overall good results. Moreover, it is known that tensile strength loss can be further minimized by the addition of polyethylene emulsion for softening of the fabric, reducing surface hardness and brittleness of the fabric. Therefore, this method showed very good promise of combined direct dyeing and resin finishing with improved wash fastness properties. This process also offers increased applicability of direct dyes with good wash fastness properties. Therefore this new technique exhibited advantages of such as reduction of chemicals, energy, time of treatments and hence it leads to sustainable production with competitive age.

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