Simultaneous Acid Dyeing and Modified DMDHEU Finishing of Cotton Fabrics for Process Intensification

Mangesh D. Teli[1] *and Oliyad Ebba Gurmu[2]

[1]Prof., Dept. of Fibres and Textile Processing Technology, Institute of chemical Technology, Maharashtra, India

[2]M.Tech, Dept. of Fibres and Textile Processing Technology, Institute of chemical Technology, Maharashtra, India.

---****---

Abstract - *The necessity to meet the growing demand of consumers led to the evolution in functional finishes. Textiles should satisfy the functional, comfort, aesthetic, and ecological requirements. In the present era the main focus is given to develop eco-friendly technologies that would provide an opportunity for developing a sustainable environment. In this work simultaneous acid 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 modified DMDHEU and acid dyes; it was one-step simultaneous application of modified DMDHEU along with different concentration of acid dye on ready for dyeing (RFD) cotton fabric. 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 show an improvement in the surface colour strength compared to that of ordinary RFD cotton fabric when separately dyed with acid dye. Also the wash fastness levels were very high. Both processes, two stage conventional acid dyeing and resin finishing and single stage simultaneous acid dyeing and resin finishing show comparable CRA values. Moreover, this process also creates possibility of selected acid dyes applicable on cotton fabrics, which otherwise not possible. Also, this technique was found to offer advantages of reduction of energy, time of treatments and hence cost of production, giving a competitive age.*

Key Words:* *Cotton fabric, Acid Dye, Modified DMDHEU, Crease Recovery, K/S, Tensile Strength, Wash Fastness

1. 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. Currently it's known that to sustain in globalized textile market, it is mandatory 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 [1]. Heating of water, drying of fabric, curing of polymer applied on fabric and heat settings are energy intensive wet processing operations. It is still desirable to think of such processes or formulations, which would result in lowering of energy consumption as well as costs [2-4]. Taking this into consideration, the dyers and finishers are trying to lower the energy consumption by modifying, shortening, and combining various processes. 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 effecting both treatments in a single operation were reported and simultaneous dyeing and finishing (SDF) is an attempt in this direction of saving energy, cost and time [5].

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 [5]. 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 [6]. Among all the conventional resins used nowadays, DMDHEU is commercially widely accepted in industry due to its good crease recovery angle, fewer tendencies to impart stiffness, no tendency to affect light fastness of dyed material, cost effectiveness and easy availability [7]. In spite of all the above advantages, DMDHEU suffers from a major drawback that formaldehyde released by this cross-linking agent often causes skin irritation. Also, skin sensitization due to continuous use of durable press cotton fabrics in many cases leads to dermatitis. The formaldehyde combines with the protein in the skin by nucleophilic addition at carbon atom and the complex formed (haptan/formaldehyde carrier/protein) is responsible for sensitization [8]. Some earlier reports are available in literature on single step process for dyeing and easy care resistant finishing of cotton and its blends [9-18].

Therefore, in present study, acid dyes along with the modified DMDHEU (low formaldehyde) have been used for simultaneous dyeing and finishing of cotton fabric and the effect of process parameters on fabric properties studied. Cotton was cross-linked using modified dimethylol dihydroxy ethylene urea (DMDHEU) using ammonium sulphate as catalyst with acid dyes by pad-dry-cure method. 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, weight add-on and washing fastness. Dye-uptake versus resin concentration and crease recovery angle versus resin concentration were analysed to establish the relation between them. The results of this exploration have been presented in this paper.

2. MATERIALS AND METHODS

2.1 Materials

Fabric

The ready for dyeing (RFD) cotton fabric (100 GSM) was supplied by Piyush Sindycate, Mumbai.

Dyes

Dyes used were Telon Red FRL (C.I Acid Red 337) supplied by DyStar India and Metalan Yellow M-2GLN (C.I Acid Yellow 129) supplied by Atul Ltd.

Chemicals

Cresotex ULFC (modified DMDHEU) was supplied by Associated Chemicals. Saralink ULF (modified DMDHEU) was supplied by Sarex Chemical Pvt. Limited, Mumbai. Sodium carbonate and acetic acid of laboratory grade were supplied by S D Fine Chemicals, Mumbai and non- ionic detergent, Auxipon NP, was supplied by Auxichem Pvt. Limitted, Mumbai.

2.2. Methods

Cotton fabric was subjected to pre-treatment, exhaust dyeing of control samples and simultaneous dyeing and finishing.

Pre-treatment

The cotton fabric was washed with 5 g/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 minutes. Fabric was then washed with hot and cold water to make it free from alkali.

Exhaust dyeing of Acid Dyeing

Exhaust dyeing for control sample was carried out in Rota dyer machine, keeping the material to liquor ratio (MLR) 1: 30. The d yeing was carried out with 1% dye on the weight of fabric (owf). pH of the dye bath was maintained to be 3-4 using acetic acid. The fabric samples were introduced into the dye bath at room temperature (RT) and the temperature was raised at a gradient of 2ºC/min to 85ºC. The dyeing was continued at this temperature for 60 minutes. After dyeing, the fabrics were rinsed, washed and dried in the oven at 80ºC for 10 min.

Padding

The fabric samples were padded through the dye solution at RT. Then padded samples were dried at 80ºC for 5 min and cured at 150ºC for 3 minutes using stenter.

Simultaneous Acid Dyeing and Resin Finishing

Samples to be treated were padded through the bath containing varying concentration of dye and modified DMDHEU. For formulation of the padding solution Saralink ULF (Modified DMDHEU) was used with C.I Acid Red 337 and Creasotex ULFC (Modified DMDHEU) was used for C.I Acid Yellow 129. The catalyst concentration used was 10% of the concentration of modified DMDHEU which was used along with dye. Then the padded samples were dried at 80ºC for 5 min and then cured at 150ºC for 3 minutes using stenter. Finally the treated samples were washed off with solution containing 5g/l non-ionic surfactant at 50ºC for 20 minutes.

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;

$$\% \text{ Increase in CRA} = [(Y-X)/X] * 100$$

Where, X and Y are CRA readings of untreated and treated samples, respectively.

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 Kubelka Munk 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 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;

Loss in tensile strength, (%) = [(X-Y)/X]*100

Where, X and Y are breaking strength readings of untreated and treated samples respectively.

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 weighing. Add-on (%) was then calculated using formula;

$$\text{Add on, } (\%) = \frac{Y - X}{X} \times 100$$

Where, X is weight of samples in grams before treatment and Y is weight of samples in grams after simultaneous dyeing and finishing.

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 Rota machine. 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).

3. RESULTS AND DISCUSSION

Fabric samples were padded through the bath containing dye (5 g/l, 10 g/l, 15 g/l, 20 g/l) and modified DMDHEU (60gpl, 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.

3.1. Effect of modified DMDHEU on CRA Properties of Simultaneous Dyed and Finished Fabric

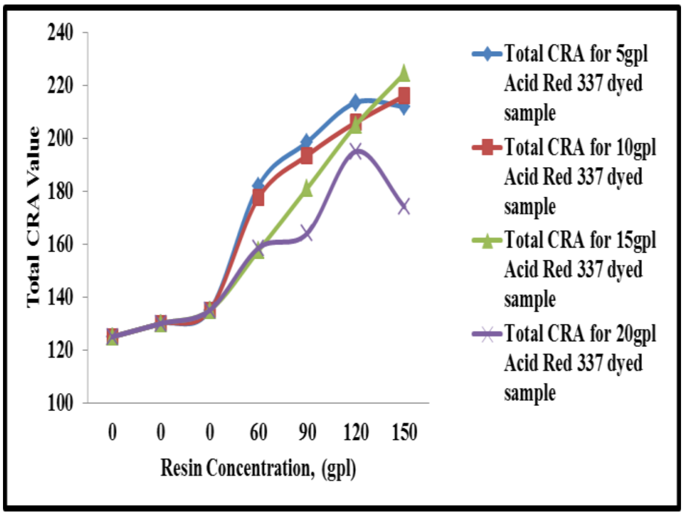

Fig-1: Effect of Saralink ULF on CRA Values of simultaneously dyed and finished sample with C.I. Acid Red 337.

Results in the Table-1 and Fig-1 indicate that CRA of the treated samples increased with increasing concentrations of modified DMDHEU (Saralink ULF). The maximum CRA value obtained was around **224º** and percent increase in CRA value over RFD fabric, exhaust dyed and padded fabric was around 79,72 and 66%, respectively.

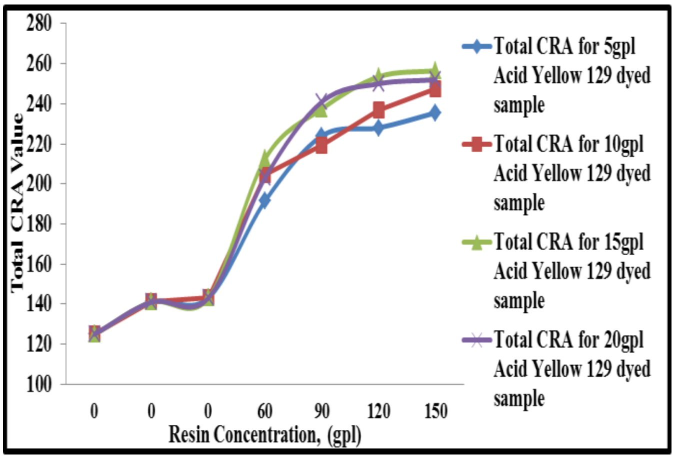

Fig-2: Effect of Creasotex ULFC on CRA Value of simultaneously dyed and finished sample with C.I. Acid yellow 129.

The results in Fig-2 show that as the concentration of modified DMDHEU increased, the CRA of Creasotex ULFC treated fabric sample also incresead. The maximum CRA obtained for the simultanously dyed sample with C.I Acid Yellow 129 and finished with Creasotex ULFC was around **250º** and the percent increase in CRA value over RFD fabric, exhaust dyed and padded fabric was around 100,80 and 80, respectively. Increase in CRA as a result of increase in concentration of low formaldehyde DMDHEU indicates higher extent of cross-linking between cellulose polymer chains because of increased concentrations of modified DMDHEU. Simultaneous dyeing and finishing might have occurred due to the reaction of the dye with the cotton fabric, through a cross-linking agent. In that case relatively less CRA value is observed compared to the sample treated with modified DMDHEU and catalyst because of less extent of the crosslinking of the modified DMDHEU with fibre as some of it is spent on reacting with the dye.

Table-1: CRA Values for Simultaneous Dyed and Finished Fabric Using C.I. Acid Red 337 with Saralink ULF and C.I. Acid Yellow 129 along with Creasotex ULFC.

Resin Concentration (gpl)	Dye Concentration (gpl)	Total CRA (^{0})		Increase (%) over RFD Fabric		Increase(%) over Exhaust Dyed Fabric Sample		Increase (%) over Padded Fabric Sample	
		C.I Acid Red 337	C.I Acid Yellow 129	C.I Acid Red 337	C.I Acid Yellow 129	C.I Acid Red 337	C.I Acid Yellow 129	C.I Acid Red 337	C.I Acid Yellow 129
0	0	125.00	125.00	0.00	0.00	-	-	-	-
0	1% (owf)	130.00	141.00	4.00	12.80	0.00	0.00	-	-
0	5	135.00	143.00	8.00	14.40	3.85	1.42	0.00	0.00
60	0	180.00	203.00	44.00	62.40	56.15	27.65	33.33	41.95
60	5	182.00	191.5	45.60	53.20	40.00	35.82	34.81	33.92
90	5	198.50	224.00	58.80	79.20	52.69	58.86	47.03	56.64
120	5	213.50	228.00	70.80	82.40	64.23	61.70	58.15	59.44
150	5	212.00	235.5	69.60	88.40	63.08	67.02	57.04	64.68
60	10	177.50	204.5	42.00	63.60	36.53	45.03	31.48	43.01
90	10	193.50	219.5	54.80	75.60	48.85	55.67	43.33	53.49
120	10	206.00	237.00	64.80	89.60	58.46	68.085	52.59	65.73
150	10	216.00	247.5	72.80	98.00	66.15	75.53	60.00	73.07
60	15	157.50	212.5	26.00	70.00	21.15	50.71	16.67	48.60
90	15	181.00	237.5	44.80	90.00	39.23	68.44	34.07	66.08
120	15	205.00	253.5	64.00	102.80	57.69	79.78	51.85	77.27
150	15	224.50	256.5	79.60	105.20	72.69	81.91	66.29	79.37
60	20	158.50	203.00	26.80	62.40	21.92	43.97	17.41	41.96
90	20	164.00	241.00	47.20	92.80	41.54	70.92	36.29	68.53
120	20	195.00	250.00	64.00	100.00	57.69	77.31	51.85	74.83
150	20	174.00	252.00	58.00	101.60	51.92	78.72	46.29	76.22

3.2. Effect of Modified DMDHEU on K/S Properties of Simultaneous Dyed and Finished Fabric

Table-2: K/S value for Simultaneous Dyed and Finished Fabric with C.I. Acid Red 337 and Acid Yellow 129

Dye Concentration (gpl)	Resin Concentration (gpl)	K/s Value		Increase (%) in K/S over 1% (owf) exhaust dyed sample	
		C.I Red 337	C.I Yellow 129	C.I Red 337	C.I Yellow 129
0	0	0.0000	0.0000	-	-
1% (owf)	0	0.0019	0.1700	0.00	0.00
5	0	0.0189	0.2100	894.74	23.53
0	60	0.0000	0.0000	-	-
5	60	0.0961	0.4600	4,957.89	170.59
5	90	0.1163	0.4500	6,021.05	164.71
5	120	0.1408	0.5500	7,310.53	223.53
5	150	0.1922	0.5900	10,015.79	247.06
10	60	0.1750	0.6047	9,110.53	255.71
10	90	0.1726	0.6132	8,984.21	260.71
10	120	0.1979	0.8503	10,315.79	400.18
10	150	0.2341	0.7537	12,221.05	343.35
15	60	0.2043	0.7142	10,652.63	320.12
15	90	0.2437	0.9090	12,726.32	434.71
15	120	0.2338	1.5508	12,205.26	812.23
15	150	0.4234	1.6225	22,184.21	854.41
20	60	0.2102	0.9520	10,963.16	460.00
20	90	0.3099	1.2350	16,210.53	626.47
20	120	0.2904	1.6750	15,184.21	885.29
20	150	0.3837	1.8130	20,094.74	966.47

Results from the Table-2 reveal that as the concentration of resin increased the K/S values of the treated samples increased significantly for both C.I Acid Red 337 and C.I Acid Yellow 129 and the samples treated using highest concentration of modified DMDHEU gave very high increase in K/S (%) over that of the untreated ones. With increase in the concentration of modified DMDHEU, increased amounts of dye is getting fixed with the cross-linking sites of modified DMDHEU on one hand and it also reacts with the fabric on the other hand. Sample treated with modified DMDHEU and catalyst without dye, showed no coloration, but CRA of these sample were slightly higher as compared to the one treated with modified DMDHEU, catalyst and dye as explained earlier. Addition of dye, catalyst and cross-linking agent to the pad bath together however showed that simultaneous dyeing and finishing was successfully achieved. Acid dyes are non-planar in structure and have no affinity for cellulosic fabrics. Hence, they tend to stain the treated fabrics and were not considered fit for cellulosic fabric.

Simultaneous dyeing and finishing has occurred due to the reaction of the dye with the cotton fabric through cross-linking agent and relatively better K/S values were obtained compared to the controlled sample which almost shows just tinting and no significant colouration.

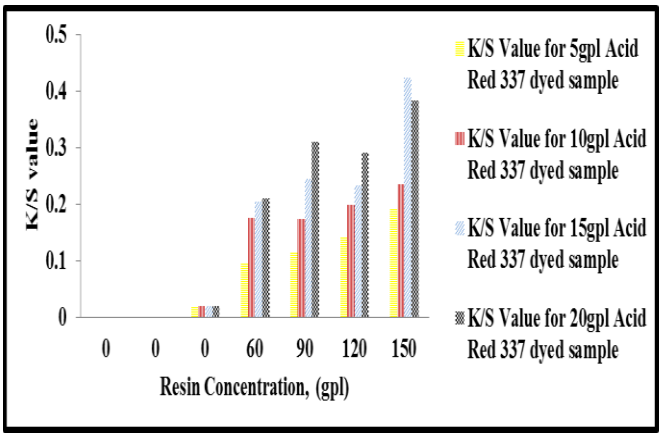

Fig-3: Effect of Saralink ULF on K/S Values of simultaneously dyed and finished sample with C.I. Acid Red 337.

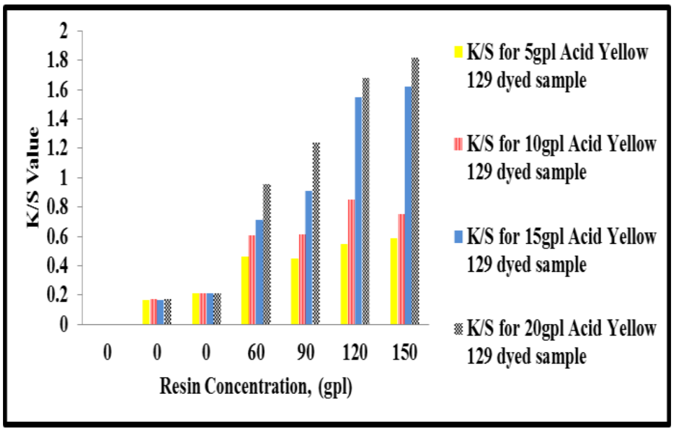

Fig-4: Effect of Creasotex ULFC on K/S Value of simultaneously dyed and finished sample with C.I. Acid yellow 129.

The Fig-3 reveals that as the concentration of resin increases the K/S value of the simultaneously dyed and finished sample with C.I. Acid Red 337 and Saralink ULF treated samples increased significantly and the samples treated using highest concentration of modified DMDHEU (Saralink ULF) gave very high increase in K/S (%) over untreated ones. Fig-4 further supports this behavior for Creasotex ULFC resin for C.I Acid Yellow 129. The increase in K/S might be due to the increased reaction of resin with fabric on one side and with dye on the other, thus fixing the dye on the fibre, which otherwise difficult to retain on the fabric.

3.3. Effect of modified DMDHEU on Tensile Strength Properties of Simultaneous Dyed and Finished Fabric

Results in the Table-3 indicate that breaking strength value for both simultaneously dyed and finished fabric with C.I. Acid Red 337 using Saralink ULF and C.I Acid Yellow 129 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 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.

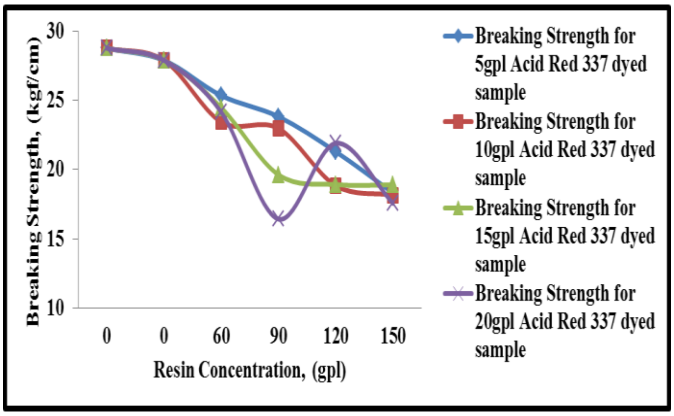

Fig-5: Effect of Saralink ULF on Tensile strength loss of simultaneously dyed and finished sample with C.I. Acid Red 337.

The Fig-5 shows that the reduction in tensile strength with increase in resin concentration for C.I. Acid Red 337 dye and Saralink ULF resin. The sample treated using highest concentration of modified DMDHEU made the fabric weaker and gave relatively high percent loss in tensile strength over untreated ones which is around 30%. The loss in tensile strength is due to the increased crosslinking between the cellulosic polymer and the resin, creating weak spots and very poor load distribution among the polymeric chains.

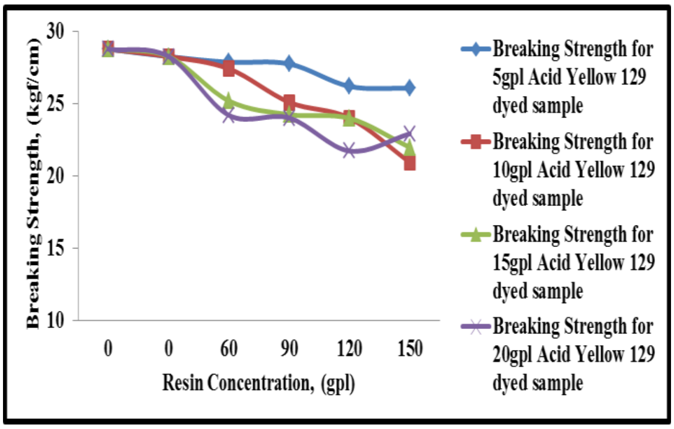

Fig-6: Effect of Creasotex ULFC on Tensile Strength loss of simultaneously dyed and finished sample with C.I. Acid yellow 129.

The Fig-6 shows that the similar trend for reduction in tensile strength with increase in resin concentration for C.I. Acid Yellow 129 dye and Creasotex ULFC resin. 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 Crosslinking increases the polymer chain rigidity and ability to share the stress 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 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 bringing down the tensile strength of the fabric.

Table-3: Breaking Strength value for Simultaneous Dyed and Finished Fabric with C.I. Acid Red 337 and Acid Yellow 129

Dye Concentration (gpl)	Resin Concentration (gpl)	Breaking Strength (Warp)		Loss in Tensile Strength (Warp), (%)	
		C.I Acid Red 337	C.I Acid Yellow 129	C.I Acid Red 337	C.I Acid Yellow 129
0	0	28.76	28.76	0.00	0.00
5	0	27.89	28.25	3.03	1.77
5	60	25.34	27.86	11.89	3.13
5	90	23.82	27.74	17.18	3.55
5	120	21.29	26.19	25.97	8.94
5	150	18.31	26.06	36.33	9.39
10	60	23.43	27.41	18.53	4.69
10	90	22.97	25.09	20.13	12.76
10	120	18.84	23.98	34.49	16.62
10	150	18.15	20.93	36.89	27.23
15	60	24.47	24.19	14.92	18.89
15	90	19.62	24.01	31.78	16.52
15	120	18.91	23.99	34.25	16.56
15	150	18.89	22.92	34.32	20.31
20	60	24.14	25.18	16.06	12.45
20	90	16.42	24.24	42.91	18.65
20	120	21.90	21.72	23.85	24.48
20	150	17.56	21.97	38.94	23.61

3.4. Effect of modified DMDHEU on Weight Add-On Properties of Simultaneous Dyed and Finished Fabric

Table-4: Weight Add-on, (%) value for Simultaneous Dyed and Finished Fabric with C.I Acid Red 337 and C.I Acid Yellow 129

Dye concentration (gpl)	Resin Concentration (gpl)	Weight Add-on, (%)	
		C.I Acid Red 337	C.I Acid Yellow 129
5	60	0.70	0.66
5	90	0.90	0.80
5	120	1.00	1.80
5	150	1.20	2.20
10	60	1.45	0.68
10	90	1.56	1.35
10	120	2.54	2.00
10	150	2.97	2.30
15	60	1.47	1.00
15	90	2.10	1.40
15	120	1.95	2.00
15	150	2.26	2.50
20	60	2.25	1.15
20	90	2.77	1.80
20	120	3.59	2.30
20	150	3.87	3.00

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. Increased amounts of resin are 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 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.

The Fig-7 shows there exists positive dependence of weight add-on on the resin (Saralink ULF) concentration. This is 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 crosslinking between the dye and the resin in the fibre.

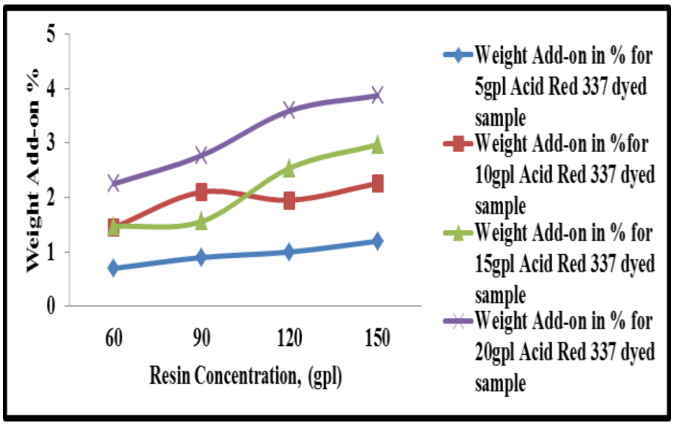

Fig-7: Effect of Saralink ULF on Weight Add-On of simultaneously dyed and finished sample with C.I. Acid Red 337.

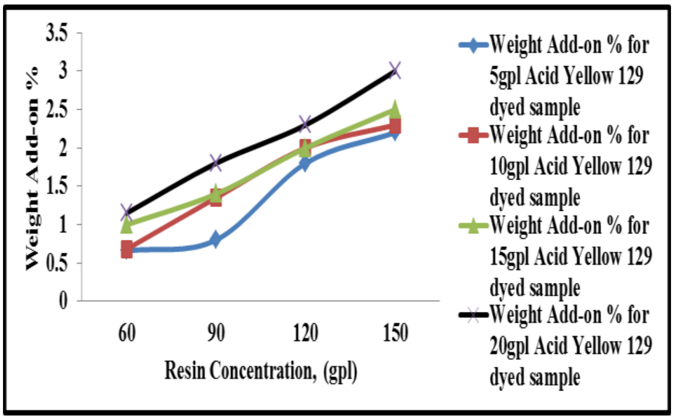

Fig-8: Effect of Creasotex ULFC on Weight Add-on % of simultaneously dyed and finished sample with C.I. Acid yellow 129.

The Fig-8 shows similar trend of the effect of concentration of Creasotex ULFC on weight add-on of simultaneously dyed and finished sample with C.I. Acid Yellow 129.

3.5. Effect of modified DMDHEU on Washing Fastness Properties of Simultaneous Dyed and Finished Fabric

ISO 105:C02 Washing fastness ratings show that the simultaneously dyed and resin finished fabric exhibited good fastness properties with low formaldehyde (modified) DMDHEU. Acid dyes have no affinity for the cellulosic fibres due to their non-planar structures and small molecular size and thus these dyes only stain the cotton fabric in exhaust dyeing without other fixing agents. However, in the above simultaneous dyeing and finishing process, as the concentration of modified DMDHEU increased, dye fixation also increased. From the Table-5 it is clear that as the concentration of the resin increased it exhibited a positive effect on the amount of dye cross linked with the fibre polymer which in turn affects the fastness properties of the fibre positively. Generally seen that as the concentration of resin increased, the fatness to washing up to 3-4 observed which was good to very good for acid dyeing indicating that the dye was fixed with covalent bonding.

Table-5: ISO 105:C02 washing fastness results of Simultaneous dyed and finished fabric with C.I. Acid Red 337 and C.I Acid Yellow 129

Dye concentration (gpl)	Resin Concentration (gpl)	Washing Fastness	
		C.I Acid Red 337	C.I Acid Yellow 129
1% (owf)	0	1-2	1-2
5	0	1	1-2
5	60	2	2-3
5	90	2-3	2-3
5	120	3	2-3
5	150	3-4	2-3
10	60	2	2-3
10	90	2-3	2-3
10	120	3	2-3
10	150	3	2-3
15	60	2	2-3
15	90	3	3-4
15	120	3-4	3-4
15	150	3-4	3-4
20	60	2	3-4
20	90	3	3-4
20	120	3-4	3-4
20	150	3-4	3-4

4. CONCLUSION

The aims of this study was to examine the possibility of using selected acid dyes and modified DMDHEU (Saralink ULF and Creasotex ULFC) in simultaneous dyeing and finishing, with suitable catalyst and compare the same with conventional way of processing. It was observed that the individual presence of catalyst, crosslinking agent and dye alone in the padding bath had no effect on the either dyeing or finishing properties of the treated fabrics. Although catalyst and resin together increased cross-linking, the dye and resin or dye and catalyst did not show any cross linking and positive contribution to CRA, nor dyeing except simple tinting. Only when all the three that is the resin, catalyst and dye were present, there was simultaneous dyeing as well as finishing which was reflected in increased extent of K/S values as well as CRA. This clearly indicates that the acid dye gets fixed through multi-functional resin, which is also supported in our earlier work [5].

CRA values of various simultaneous dyed and finished samples were found to be around 200-250º which is 37.5-100% increase over that of the RFD fabric and these values are good for wrinkle free cotton fabric. The ISO II wash fastness was found to be 3-4 or good to very good. Of course there was loss in tensile strength (%) which was inevitable; however, this could be controlled by controlling resin concentration and also adding polyethylene emulsion. Hence, this method gives us the novel route of application of acid dyes on cotton as well as simultaneously finishing the same and this offers a unique continuous dyeing and finishing process with saving of energy, chemicals and costs with higher productivity.

ACKNOWLEDGEMENT

One of the authors, Oliyad Ebba Gurmu, gratefully acknowledge the authorities of Institute of Chemical Technology (ICT), India, and Ethiopian Textile Industry development institute (ETIDI), Ethiopia, for giving the opportunity of carrying out this research work in ICT.

REFERENCES

[1] Malika SK. & Kumar S., "Simultaneous Dyeing and Finishing of Cotton Fabric Using Reactive Dyes and Citric Acid," Indian Journal of Fibre & Textile Research, Vol. 30, December 2005, pp 444-450.

[2] Teli MD, Samanta KK, Pandit P, Basak S, Chattopadhyay SK. Low-temperature dyeing of silk fabric using atmospheric pressure helium/nitrogen plasma. Fibers and Polymers. 2015 Nov 1;16(11):2375.

[3] Teli MD, Pandit P, Basak S. Coconut shell extract imparting multifunction properties to ligno-cellulosic material. Journal of Industrial Textiles. 2017 Jan 6:1528083716686937.

[4] Teli MD, Samanta KK, Pandit P, Basak S, Gayatri TN. Hydrophobic silk fabric using atmospheric pressure plasma. International Journal of Bioresource Science. 2015;2(1):15-9.

[5] Teli, M. D., S. P. Pandian, and Vyas U. V.. "Simultaneous Acid Dyeing and Resin Finishing of Cotton Fabrics," Indian Journal of Fibre & Textile Research, Vol. 15 (1990), pp. 18-22.

[6] Dehabadi, V.A, H.J. Buschmann, and J.S Gutmann. "Durable Press Finishing of Cotton Fabrics: an overview." Textile Research Journal, Vol. 83, 2013, pp. 1974-1995.

[7] Chattopadhyay, D. P., D. N. Sharma, and P. De. "Studies on Formaldehyde-Free Crease-Resistant Finishing of Cotton Fabric Using Citric Acid and Selective Chemical Additives." Vol. 24, December 1999, pp. 284-289.

[8] Bhattacharyya, N., Doshi, B. A., Sahasrabudhe, A. S., & Mistry, P. R. (1993), " Novel Formaldehyde Scavengers in Resin Finishing of Cotton Fabrics," American Dyestuff Reporter, 82, 96-96.

[9] Ibrahim, N. A., and K. Haggag. "Concurrent Dyeing and Finishing: V. One-bath Dyeing and Easy-care Finishing of Cotton Fabrics with Acid Dyestuffs and N-methylol Compounds Using Different Catalytic Systems." Dyes and Pigments Vol. 7, 1986, pp. 351-363.

[10] Ibrahim, N. A., and H. L. Hanna. "Concurrent Dyeing and Finishing. 1. Novel-Approach to Simultaneous Dyeing and Finishing of Pet-Cotton Blend with One Dye Class," American Dyestuff Reporter 73.10 (1984): 36.

[11] Li, Shiqi, et al. "One-Step Pad Dyeing and DP Finishing of Cotton: Part 1. Reactive Dyes with DMDHEU." AATCC Journal of Research, Vol. 2, 2015, pp. 6-12.

[12] Kamel, M., A. Hebeish, and A. Al-Aref., "Simultaneous Dyeing and Finishing of Acrylamidomethylated Cotton Fabrics," Textile Research Journal, Vol. 45, 1975.

[13] Rattee, I. D. "The combined dyeing and finishing of cellulosic fabrics." Coloration Technology, Vol. 78, 1962, pp. 69-76.

[14] Reinhardt, Robert M., and Jett C. Arthur. "Wrinkle-Resistant Cotton by Photo-Initiated Reaction with N-Methylolacrylamide Followed by Crosslinking Reactions1." Textile Research Journal, Vol. 50, 1980, pp. 261-267.

[15] Kaenthong, Sirinun. "Combining Reactive Dyeing and Finishing of Cotton in One Stage Process." (1998).

[16] Ibrahim, N. A. "Concurrent dyeing and finishing. XIII: Role of Acrylamide in Simultaneous Dyeing and Finishing of PET/C Blend Fabric," Cellulose chemistry and technology, 29.1 (1995): 77-86.

[17] Mortazavi, S. M., M. A. Alsharif, and M. Jannesari. "A Study on Simultaneous Fixation of Reactive Dye Printing and Crease Resist Finishing on Cotton Fabric (Effect of DMDHEU Concentration, Types of Catalyst and Drying Conditions)." (2006).

[18]McBurney, Douglas H. "An Investigation of Simultaneous Phosphonic Acid Reactive Dyeing and Durable Press Finishing Cotton Fabric with Phosphonated CI Acid Red 1 Dye and Dimethylolethyleneurea," 1984.

BIOGRAPHIES

Prof. (Dr.) M. D. Teli a Fellow of CSIR-CNRS (France), Maharashtra Academy of Science, Honorary F.T.A and Shiksha Ratna, has guided 120 Master's and Doctoral students with over 370 publications/conference presentations and edited 25 books. He is an Independent Director of Siyaram Silk Mills, Chairman of Editorial Board of JTA and a Managing Trustee of Baha'i Lotus Temple, Delhi.

Mr. Oliyad Ebba Gurmu has completed his B. Sc in Textile Engineering. Currently, he is pursuing M. Tech at Institute of Chemical Technology, Mumbai. His research area is process intensification for value addition in textile which includes: Simultaneous Dyeing and Finishing, Nanotechnology, Multifunctional finishing of textile materials.