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Effect of Mass to Liquor Ratio on Dyeing Process

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ABSTRACT

In Indian textile industry, the number of factors affects on energy consumption. A detailed study was conducted for small the scale textile industry in depth for the various processes involved, chemicals required, operating parameters, mass to liquor ratio(MLR), energy requirements during processes including different losses etc. and to study effect of MLR on dyeing process in order to achieve acceptable good quality of cotton coloured products. The process temperature and time, water inlet temperature and liquor ratio were found to be the main parameters that affect energy destruction rates. In addition, some technical information's has been included with schematics processes used for production as also machineries.

Introduction:

Dyeing process is broadly governed by fabric type, dye type, machine type, MLR, time, temperature, pH of the fabric and liquor, type of auxiliary used etc. Any minor variation in any of these variables causes problem in dye reproducibility, though it is possible to achieve reproducibility in dyeing results. By standardizing each and every variable we can achieve consistent reproducible results and satisfy customer needs. To maintain Standard MLR in processing is very important, it should be check in the time of dyeing.[2][3]

The preparation for spinning of raw material components into consistent and continuous fiber filaments (i.e. threads or yarn). The production of continuous fiber is hand or machine processed. Figure 1 shows the flow chart for dyeing process.

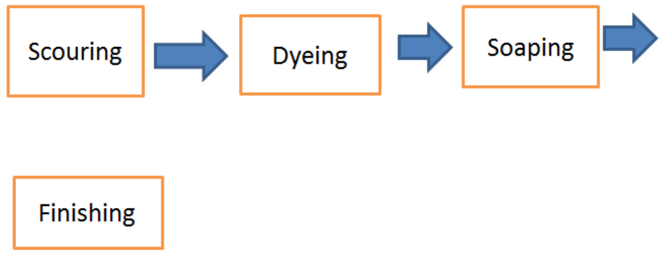

Fig 1. Flow diagram for dyeing process

Scouring is the process of removal of natural oil substances like waxes, fats and pectin's as well as added impurities like lubricating oil, dust, dirt and residual starch in cotton materials. Scouring means holding mixture of water and scouring agent like saracol at high temp.

Dyeing is a process of driving the cheese with dyes at 60^{0}C for one hour. Temperature and time of dyeing process is depends on type of shade whether it is dark or light.

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Soaping is post process in dyeing. Soaping is the process of removal of extra dyestuff which is coagulated on cheese. Soaping is done at 80-90^{0}C in presence of soaping agents.

Finishing is a last process in dyeing. It includes two hot washes but for dark shade more than two hot washes are given till bath is not clear. After finishing, yarn is passed through hydro extracting machine for further processing.[8][10]

Dyeing is a complex process, where number of variables is involved. Material (mass) to liquor ratio is most important feature of dyeing typically machines with MLR from 1:4 to 1:10 are commonly used however it is always preferred a machine with lowest possible liquor ratio, without affecting the quality of dyeing. As MLR increases the depth of the shade decreases and strength of the shade also decreases. To achieve right first time dyeing for such typical shade MLR should taken more than optimum value. But strength decreases but this problem can avoid by increasing depth of shade. [3]

Role of MLR with relate to following

- Quality
- Energy saving
- Costing
- Ecology

Bench Scale Experimental Results:

The study of effect of MLR in dyeing process were conducted on bench scale unit as shown in Fig.2 and the block diagram for the same is depicted in Fig.3. The variable identified for the study of effect of MLR was consistency in the dyeing (water quantity, chemicals used for processing, quality and concentration of the dye etc.), time for dyeing process and temperature of dyeing process, the observations and results presented in Table No. 1 to 6.

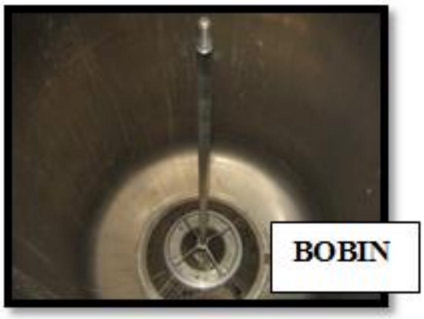


Fig 2. Bench scale experimental unit for dyeing process

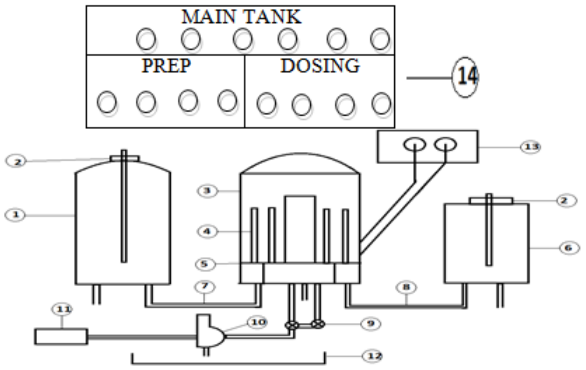


Fig 3 . Block diagram for bench scale experimental unit for dyeing process

1 .PREP TANK
2. MIXER ARRANGEMENT
3. MAIN TANK
4. SPINDLE
5. CARRET
6. DOSING TANK
7. PIPE CONNECTION PREP. TO M.T
8. PIPE CONECTION M.T TO D.T
9.IN-OUT&OUT-IN ARRANGEMEN
10. PUMP
11 .MOTOR
12.WATER RESERVOIR
13 & 14 CONTROL PANEL

Literature Review:

Khushal P et al., (2014) [1] studied that effect of pH, temperature, hardness of water on bleeding behavior of dyes. From investigation it may be concluded that washing of yarn dyed fabric should be done at pH range of 6 to 7 and below 60^0C, and water used of 30 ppm.

Jadhav et al., (2014) [2] described Dyeing process is broadly governed by fabric type, dye type, machine type, MLR time, temperature, pH of the fabric and liquor, type of auxiliary used etc. Any minor variation in any of these variables causes problem in dye reproducibility, though it is possible to achieve reproducibility in dyeing results. By standardizing each and every variable we can achieve consistent reproducible results and satisfy customer needs.

Jadhav D A. et al., (2013) [3] presented that Basic principle and methods of dyeing processes are described in terms of parameters such as temperature, liquor to water ratio, usage and requirement. This paper describes about the different dyeing processes with its properties. Adoption of process mainly depends on the availability and quality of material.

Patil et al., (2013) [4] Material to liquor ratio is most important feature of package dyeing typically machines with MLR from 1:4 to 1:10 are commonly used. As MLR increases the depth of the shade decreases and strength of the shade decreases. To achieve right first time dyeing for such typical shade MLR should taken more than optimum value but this problems can avoided by increasing depth of shade.

Gatawa et al., (2013) [5] Presented that electricity consumption has significant positive influence on textile output. Stable and reliable power supply is necessary to generate optimum production at lower cost so as to enhance utilization of idle resources, expand factor incomes, improve competitiveness and expand overall textile output.

Gawade et al., (2012) [6] presented that the textile industry holds significant status in the India and it accounts for 14% of the total industrial production. It contributes to nearly 30% of the total exports and it is the second largest employment generator after agriculture.

Elahee et al., (2011) [7] Described the techniques and technologies of heat recovery from waste water and exhaust air are analysed. Experiences prove that in most cases heat recovery requires low investment and has a low payback of normally less than 2 years. The case of the Mauritian dyeing and finishing industry is highlighted, including the possible use of a low-cost heat recovery unit made from indigenous resources.

Hasanbeigi et al., (2010) [8] presented information on energy-efficiency technologies and measures applicable to the textile industry. The guidebook includes case studies from textile plants around the world and includes energy savings and cost information when available. An analysis of the type and the share of energy used in different textile processes has carried out. Subsequently, energy-efficiency improvement opportunities available within some of the major textile sub-sectors are given with a brief explanation of each measure. The conclusion includes a short section dedicated to highlighting a few emerging technologies in the textile industry as well as the potential for the use of renewable energy in the textile industry.

Cayet et al., (2009) [9] described the study of the energetic assessment of exhaustion processes for textile fabrics using actual operational data. The process temperature and time, water inlet temperature and liquor ratio were found to be the main parameters that affect energy destruction rates. The effects of carry-over on energy destruction rates were also investigated. It was shown that, 23% and 50% of total energy destruction rate were occurred by the bleaching and the washing steps for cotton finishing, respectively, while 32% of total was accounted for the dyeing step of polyester finishing. High temperature processes had higher energy efficiency values.

Rajakumari et al., 2008 [10] have invented and studied inputs for treating textile waste water using pre-treatment, reverse osmosis and evaporator for to representative textile waste water treatment plants. Study reveals that evaporator consumes 48% of electricity, which contribute for more global warming potential than other treatment unit.

Ozturk (2004) [11] In this study, a survey has been carried out to show energy consumption, energy cost and the relationship between the energy usage and textile production.

As per the plant procedure observations taken as per the following for dark shade.

Shade- Black Process Time, t = 50min
Process Temp = 52^0c Wt-:0.980Kg MLR- 1:6

Table no.1 Bench scale data for dark shade as per the dyeing process

Time in	Time out	Process time(min)	Name of process	Particulars	Process temp.(^{0}C)
8:50	9:20	30	Scouring	To obtain Temp of 90^{0}c	
9:20	9:40	20		Holding mixture of L.F+ water	90
9:43	9:58	15		To obtain Temp of 80^{0}c	
9:58	10:08	10		Holding in main tank	80
10:00	10:20	20		Hold acid+ water in M.T.	35
10:22	10:37	15		Holding RLA & CA in main tank	35
10:37	10:47	10		mixing of colour in P.T.	35
10:47	11:07	20	Dyeing	Holding colour in M.T.	35
11:07	11:17	10		Mixing salt in P.T.	35
11:17	11:37	20		Holding mixture (salt + colour)	35
11:37	11:58	21		obtain temp mixture to 52^{0}c	52
11:58	12:28	30		Holding mixture in main tank	52
12:28	12:48	20		soda dosing from D.T.	52
12:48	1:03	15		caustic dosing	52
1:03	**1:53**	**50**		**Holding the mixture**	**52**
1:55	2:05	10		Cold wash	35
2:10	2:30	20		Acid wash	35
2:33	2:53	20		obtain temp 90^{0}c	
2:53	3:13	20		Holding mixture (saracol+ water)	90
3:15	3:30	15		obtain temp 80^{0}c	
3:30	3:40	10		Hot wash	80
3:43	3:58	15	Soaping	Acid wash	35
3:58	4:13	15		obtain temp of 80^{0}c	
4:13	4:23	10		Holding in M.T.	80
4:23	4:38	15		obtain temp of 80^{0}c	
4:38	4:48	10		Hold in M.T.	80
4:50	4:55	5		Add 6069, 210, acid, C.A	
4:55	5:05	10	Finishing	To obtain temp. 50^{0}C	50
5:05	5:35	30		Holding in main tank	50

* MLR- Mass of Cotton to Liquor ratio

Table No.2. Calculations for total theoretical energy requirements for scouring process

1) Scouring Process

Shade-BLACK Wt-0.980kg MLR-1:6

Particulars	Device	Quantity	Total mass	Cp	Temp In	Temp Out	ΔT	Q=MCpΔT	Total Process time	Heat from coil	Total heat
Unit	Main Tank	Kg	Kg	KJ/KgK	K	K	K	KJ/k	Hrs	KJ/sec	KJ
Cotton		0.98	0.98	1.34	308	363	55	72.226	2.1	0.7	5292
Water		1:6	9	4.186	308	363	55	2072.070			
L.F		1%	0.01	4.186	308	363	55	2.302			
Water in M.T		1:6	6	4.186	308	353	45	1695.330			
Cotton		0.98	0.98	1.34	363	353	-10	-13.132			
							Total	3828.796			

Table No.3. Calculations for total theoretical energy requirements for dyeing process

2) Dyeing Process

Particulars	Device	Quantity	Total mass	sp. heat (Cp)	Temp. In	Temp. Out	ΔT	Q=MCpΔT	Total process time	Heat from coil	total heat
Unit	M.T	Kg	Kg	KJ/KgK	K	K	K	KJ	Hrs	KJ/sec	KJ
RLA		0.5GPL	0.0045	4.186	308	325	17	0.320	2.08	0.7	5241.6
CA		1GPL	0.009	4.186	308	325	17	0.640			
0.192%YellowMER		0.19%	0.0019	4.186	308	325	17	0.135			
0.084% REDMEBL		0.08%	0.0008	4.186	308	325	17	0.057			
4.43% Black WNN		4.43%	0.0443	4.186	308	325	17	3.152			
Salt		80GPL	0.72	4.186	308	325	17	51.237			
Caustic		1GPL	0.009	4.186	308	325	17	0.640			
Soda		5GPL	0.045	4.186	308	325	17	3.202			
Cotton		0.980Kg	0.98	1.34	308	325	17	22.324			
Water		1:6	6	4.186	308	325	17	640.458			
Saracoal		1GPL	0.001	4.186	308	353	45	0.188			
Cotton		0.98	0.98	1.34	308	353	45	59.094			
Water		1:6	6	4.186	308	353	45	1695.330			
						Total		2476.779			

Table No 4. Calculations for total theoretical energy requirements for soaping process

3) Soaping Process

Particulars	Device	Quantity	Total mass	Cp	Temp In	Temp Out	ΔT	Q=MCpΔT	Total process time	Heat from coil	Total heat
Unit		Kg	Kg	KJ/KgK	K	K	K	KJ	Hrs	KJ/sec	KJ
Saracoal	M.T	1GPL	0.01	4.186	308	353	45	1.884	1.9	0.7	4788
Cotton		0.98	0.98	1.34	308	363	55	72.226			
Water		1:6	6	4.186	308	353	45	1695.330			
Cotton		0.980kg	0.98	1.34	363	353	-10	-13.132			
Water inM.T		1:6	6	4.186	353	308	-45	-1695.330			
Cotton		0.980kg	0.98	1.34	308	353	45	59.094			
Water inM.T		1:6	6	4.186	308	353	45	1695.330			
Cotton		0.980kg	0.98	1.34	353	353	0	0.000			
Water inM.T		1:6	6	4.186	308	353	45	1695.330			
							Total	3510.732			

Table No 5. Calculations for total theoretical energy requirements for finishing process

4) Finishing Process

Particulars	Device	Quantity	Total mass	Cp	Temp In	Temp Out	ΔT	Q=MCpΔT	Total process time	Heat from coil	Total heat
Unit		Kg	Kg	KJ/KgK	K	K	K	KJ	Hrs	KJ/sec	KJ
210	M.T	2%	0.02	4.186	308	323	15	1.256	0.66	0.7	1663
6069		3%	0.03	4.186	308	323	15	1.884			
CA		0.20%	0.002	4.186	308	323	15	0.126			
Cotton		0.98	0.98	1.34	308	323	15	19.698			
Water		1:6	6	4.186	308	323	15	565.110			
A. Acid		0.30%	0.003	4.186	308	323	15	0.188			
							Total	588.261			

Table No 6. Results

Results

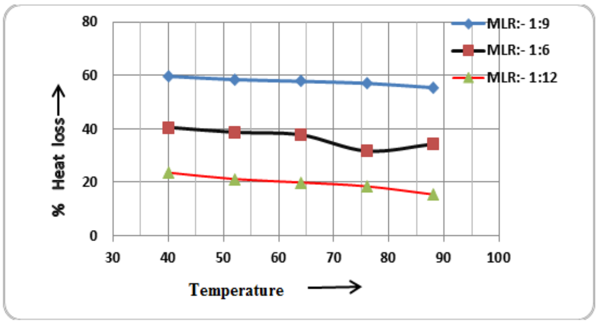
Process	Total Heat Required (KJ)	Total Heat Supplied (KJ)
Scouring	3828.796	5292
Dyeing	2476.779	5241.6
Soaping	3510.732	4788
Finishing	588.261	1663
Total	10404.57	16984.6
	Total heat loss =	6580.032
	% heat loss =	38.74%

Number of experiments conducted on bench scale unit, based on that thermal analysis for effect of MLR on dyeing process are carried out by using thermal equation Q=M× Cp× (T2-T1), where Q heat supplied, Cp specific heat, (T2-T1) process temperature difference.

As per results obtained from calculation, graph is plotted for percentage heat loss Vs temperature for 50 min time as shown in Fig4. Optimum point was determined at 64^0C and 50 min with 1:6 MLR of dyeing process. The percentage heat loss at that point is 37.77%.

Quality confirmation at optimized parameters for dyeing process:

Colour fastness is the resistance of a material to change any of its colour characteristics or extent of transfer of its colorants to adjacent white material in touch. The colour fastness is usually rated either by loss of depth of colour in original sample or it is also expressed by staining scale i.e. the accompanying white material gets tinted or stained by colour of original fabric. However, among all types of colour fastness, light fastness, wash fastness and rub fastness are considered generally for any textiles; perspiration fastness is considered specifically for apparels only



Graph1: Percentage heat loss Vs temperature at various MLR

Duff studied the light fastness and wash fastness under the standard condition (50ºC) and at 20ºC with washing formulation used in conservation work for restoring of old textiles. Some dyes undergo marked changes in hue on washing due to presence of even small amount of alkali in washing mixture, highlighting the necessity to know the pH of alkaline solution used for the cleaning of textile dyed with natural dyes. As a general rule, natural dyes show moderate wash fastness on wool, as assessed by the ISO II test.

In general, rub fastness of most of natural dyes is found to be moderate to good and does not require after treatment. However, it must be remembered that the colour fastness of natural dyes not only depends upon chemical nature and type of natural colorants, but also on chemical nature and type of mordant's being used. So a dyer must know the use of pr combination of fiber-mordant to achieve best colour fastness.

Table No. 7 Heat loss assessment for obtaining quality product after dyeing

Process Time(min)	Process Temp(^{0}c)	MLR	Rubbing Fastness	Washing Fastness	Total Heat loss (KJ)	% Heat Loss
50	40	1:6	Yes	Yes	6762.197	40.60
		1:9	Yes	Yes	9917.914	59.72
		1:12	Yes	Yes	4056.634	23.64
50	52	1:6	No	No	6580.032	38.74
		1:9	No	No	9899.7	58.46
		1:12	No	No	3713.301	21.23
50	**64**	**1:6**	**No**	**No**	**6624.667**	**37.77**
		1:9	No	No	10108.285	57.80
		1:12	No	No	3596.768	19.93
50	76	1:6	Yes	Yes	5718.902	31.70
		1:9	Yes	Yes	10266.471	57.06
		1:12	Yes	Yes	3427.836	18.48
50	88	1:6	Yes	Yes	6235.137	34.32
		1:9	Yes	Yes	10046.657	55.45
		1:12	Yes	Yes	2884.903	15.45

Yes-indicates transfer of its colorants to adjacent white material
No- indicates there is no transfer of colorants to adjacent white material

Keeping the dyeing quality in view, particularly rubbing and washing and the results obtained are presented in the Table No.7.

Conclusion

The objective was to study the effect of MLR on dyeing process and the experiments were conducted by keeping time constant and by varying temperature and MLR. Mathematical calculations have been carried out for heat consumption. It is found that temperature and MLR have the significant influence on the heat consumption.

Heat consumption increases temperature for the same consistency in the dyeing process with respect to time. The optimized values of parameters are found out for minimum heat loss. This study has wider applications for all small scale dyeing units in India. The process reliability of the system can be enhanced by integrating or combining all the process parameters, resulting in the cost per unit power consumption using reliability model. Use of reliability model will result in lower consumption of raw materials, water, dyes and energy, enabling the dyeing units in lowering the environmental pollution.

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