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Effect of Change in Process Parameters on Energy Consumption during Textile Dyeing Process

Kuldip Arun Rade[1], Vilas A. Pharande[2], Daulat. R. Saini[3]

[1]Mechanical Engineering Department, B.V.D.U. College of Engg, Pune-satara Road, Pune-46, Maharashtra, India.

[2]Mechanical Engg Department SET, Arvind Gavali college of Engg, Varye, Satara-15, Maharashtra, India.

[3]Chemical Engg Department, National Chemical Laboratory, Dr. Homi Bhabha Road, Pune-08, Maharashtra, India.

Abstract

The textile industry is one of the oldest industrial sectors in the world. 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) and energy requirements during processes including different losses etc. To study effect of process parameters on dyeing process and optimize thermal energy requirements in order to achieve acceptable good quality of cotton coloured products. The process temperature, process time, and liquor ratio were found to be the main parameters that affect energy consumption rates. In addition, some technical information's has been included with schematics processes used for production.

Keywords*:* Textile Processes, Dyeing, Thermal Energy, Process Parameters.

INTRODUCTION

In a textile industry, energy is used in different end-uses for various operations. The textile plant requires both thermal as well as electrical energy for its operation. About 80% of the energy requirement is met in the form of heat. [2] It is one of the major energy consuming industries and retains an evidence of the lowest efficiency in energy utilization. Around 23% energy is consumed in weaving, 34% in spinning, 38% in chemical processing and another 5% for miscellaneous operations. In the

textile industry, the electrical as well as thermal energy is used for i) Production Processes, ii) Lightening systems, iii) Heating, Ventilating, and Air Conditioning (HVAC). The production contributes a huge share (average 77%) of the total consumption. Lightening and HVAC take about 5 and 17%, respectively.
Dyeing process is controlled by fabric type, type, MLR, time, temperature, pH of the fabric and liquor, type of auxiliary used etc. Any minor change in any of these variables causes problem in dye product. By standardizing each and every variable one can achieve consistent results and satisfy customer needs. [2][3]

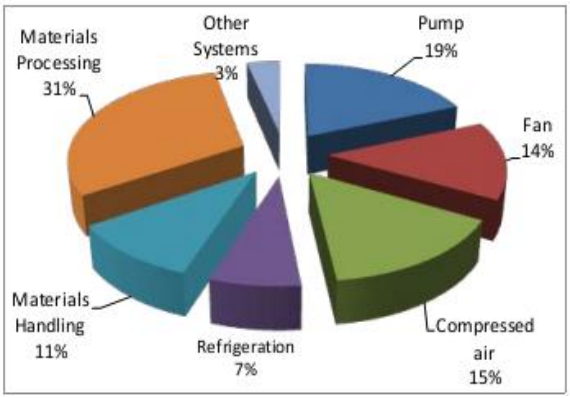


Fig.1: Breakdown of Energy Use Textile Industry

Textile process:

Figure 2 shows the flow chart for Textile process. Dyeing is the process of adding color to textile products like fibers, yarn and fabrics. Dyeing is normally done in special solution containing dyes and particular chemical material.

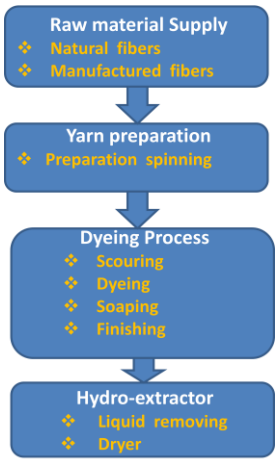


Fig.2: Textile process

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.

Dyeing is a process of driving the cheese with dyes. Temperature and time of dyeing process is depends on type of shade whether it is dark or light.

Soaping is post process in dyeing.Soaping is the process of removal of extra dyestuff which is coagulated on cheese.

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. [3][6]

Dyeing is a complex process, where number of variables/parameters is involved.

IDENTIFIED DYEING PROCESS VARIABLES:

Figure 3 reveals the different process parameters used in dyeing process.

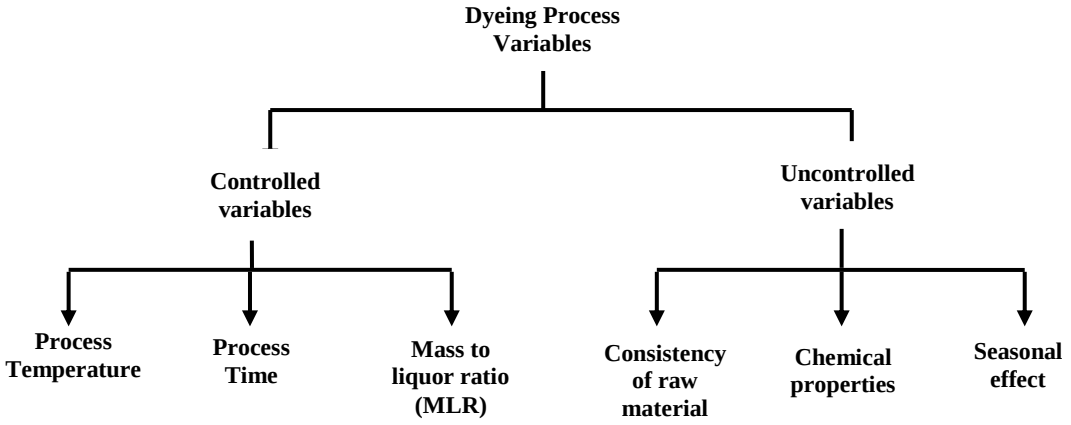


Fig.3: Dyeing Process Variables

Based on the various process parameters number of experiments were performed under the assistance of shift supervisor in research Industry "Prerana Magasvargiya Co-operative Industries Limited, Islampur, Sangli" by considering process parameters like,

i) Dyeing Process Temperature ii) Dying Process Time iii) Mass to Liquor Ratio (MLR).

Various readings were taken by keeping

i) Process time constant, varying temperature and MLR
ii) MLR constant, varying temperature and process time. [4]

EXPERIMENTAL SETUP:

1. Main Tank 2. Dosing Tank/ Preparatory Tank 3. Control Panel
4 & 5. Pump Motor Arrangement 6. Pipe Connections 7. Pressure Gauge
8. Temperature Indicator

Fig.4: Experimental Setup for Optimization of Process Parameters

PLANT ANALYSIS FOR ENERGY CONSUMPTION:

As per the plant procedure observations were taken from Prerana Magasvargiya Co-operative Industries Limited, MIDC Area, Islampur, for dark shade (Refer Table No 1) and thermal assessment was carried out for total heat required and total heat supplied as shown in Table 2.

PLANT ANALYSIS WITH PREVIOUS PROCESS PARAMETERS:

Shade- Black **Process time = 65 min** **Process Temperature = 50°C**

Wt = 0.980 kg **MLR = 1:6**

Table 1: Bench scale data for dark shade as per the dyeing process

Time in	Time out	Process time(min)	Name of Process	Particulars	Process temperature(^{0}C)
10:00	10:25	30	Scouring	To obtain temperature of 90^0 C	
10:25	10:45	20		Holding mixture of L.F+ water	90
10:48	11:03	15		To obtain temperature of 80^0 C	
11:05	11:15	10		Holding in main tank	80
11:19	11:39	20		Hold acid+ water in M.T.	35
11:43	11:58	15		Holding RLA & CA in main tank	35
12:03	12:13	10		Mixing of colour in P.T.	35
12:15	12:35	20	Dyeing	Holding colour in M.T.	35
12:40	12:50	10		Mixing salt in P.T.	35
12:52	1:12	20		Holding mixture (salt + colour)	35
1:15	1:35	20		Obtain temperature mixture to 60^0 C	60
1:37	2:07	30		Holding mixture in main tank	60
2:07	2:27	20		Soda dosing from D.T.	60
2:30	2:40	10		Caustic dosing	60
2:42	**3:47**	**65**		**Holding the mixture**	**50**
3:50	4:00	10		Cold wash	35
4:03	4:23	20		Acid wash	35
4:25	4:45	20		obtain temperature 90^0 C	
4:47	5:07	20		Holding mixture (saracol+ water)	90
5:10	5:25	15		Obtain temperature 80^0 C	
5:28	5:38	10		Hot wash	80
5:40	5:55	15	Soaping	Acid wash	35
5:58	6:13	15		Obtain temperature of 80^{0}C	
6:15	6:25	10		Holding in M.T.	80
6:27	6:42	15		Obtain temperature of 80^{0}C	
6:45	6:55	10		Hold in M.T.	80
6:58	7:03	5		Add 6069 ,210 ,acid , C.A	
7:05	7:15	10	Finishing	To obtain temperature 50^{0}C	50
7:18	7:48	30		Holding in main tank	50

Thermal Analysis for Previous Operating Condition:

With the help of these controlled process parameters thermal assessment was carried out for total heat required and total heat supplied which is enumerated in Table 2

Table 2: Thermal Analysis of Dyeing process for previous parameters

Process	Total Heat Required(kJ)	Total Heat Supplied(kJ)	% of excess heat supplied
Scouring	2572.98	3124.80	18
Dyeing	1911.61	6300.00	70
Soaping	4627.81	4788.00	03
Finishing	399.51	1663.00	76
Total heat utilized	9511.91	15875.80	40
	Total heat loss =	6363.88	
	Total % heat loss =	40 %	

As per the Prerana Magasvargiya Co-operative Industries Ltd., plant procedure, data obtained from Industry and literature review observations were taken. From Incubation Center, Ichalkarnji, Kolhapur (DKTE Centre of Excellence in Nonwovens, Supported by Ministry of Textile, Govt of India) and data obtained from research Industry the values of MLR used for dyeing process varied in between 1:6 to 1:12, whereas process time varied from 50 min to 65 min and process temperature was taken from 40°C to 70°C.

EFFECT OF CHANGE IN PROCESS PARAMETERS ON HEAT CONSUMPTION DURING DYEING PROCESS: (With Modified Parameters)

- **Plant Analysis for Constant MLR, Varying Process Temperature and Process Time:**

Based on above data the selected the process parameters are, constant MLR as 1:6, varying process time such as 50 min, 60 min, 65 min and varying process temperature such as 40°C, 50°C, 60°C, 70°C for experimentation [4]. With the help of these controlled process parameters thermal assessment was carried out for total heat required and total heat supplied which is enumerated in Table 3.

As per the plant procedure observations were taken for existing parameters for dark shade.

Shade- Black **Process time = 50 min** **Process Temp = 60°C**

Wt = 0.980kg **Constant MLR = 1:6**

➢ **Thermal Analysis for modified Operating Condition:**

Total Theoretical Energy Requirement Calculations for Scouring Process, dyeing process, soaping process and finishing process are performed for 1 kg of cotton and shown in Table 3.

Table 3: Thermal Analysis of Dyeing process for Constant MLR

Process	Total Heat Required(kJ)	Total Heat Supplied(kJ)	% of excess heat supplied
Scouring	2572.98	3124.80	18
Dyeing	1851.59	5443.20	66
Soaping	4627.81	4788.00	03
Finishing	399.51	1663.00	76
Total heat utilized	9451.89	15019.40	37
	Total heat loss =	5567.51	
	Total % heat loss =	37 %	

EFFECT OF CHANGE IN PROCESS PARAMETERS ON HEAT CONSUMPTION DURING DYEING PROCESS: (With Modified Parameters)

➢ **Plant Analysis for Constant Process Time, Varying MLR and Process Temperature.**

With the help of above data, the experiments were performed by keeping constant process time 50 min, varying such as MLR, 1:6, 1:9, 1:12 and varying process temperature such as 40°C, 52°C, 64°C, 76°C, 88°C.[4] Based on these controlled parameters thermal assessment was carried out for total heat required and total heat supplied. The following data was obtained as shown in Table 4.

As per the plant procedure observations were taken for modified parameters for dark shade.

Shade- Black **Const Process Time = 50 min** **Process Temp = 64°C**

Wt = 0.980Kg **MLR = 1:6**

➢ **Thermal Analysis for modified Operating Condition:**

Total Theoretical Energy Requirement Calculations for Scouring Process, dyeing process, soaping process and finishing process are performed for 1 kg of cotton and shown in Table 4.

Table 4: Thermal Analysis of Dyeing process for constant process time

Process	Total Heat Required(kJ)	Total Heat Supplied(kJ)	% of excess heat supplied
Scouring	4138.80	5292.00	22
Dyeing	3306.54	5796.00	43
Soaping	3780.73	4788.00	21
Finishing	688.26	1663.00	59
Total heat utilized	11914.33	17539.00	33
Total heat loss =		5624.67	
Total % heat loss =		33 %	

QUALITY CONFIRMATION FOR 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 wash fastness test under the standard condition at 50ºC and at 20ºC with washing formulation used in conservation work for restoring of old textiles. Keeping the dyeing quality in view, particularly rubbing and washing and the results obtained are presented in the Table 5 & 6.

- **Result Table 5:**

Heat Loss Assessment for Obtaining Quality Product after Dyeing for Constant MLR, Varying Process Time and Process Temperature

Sr. No	**Process Temp (^{0} C)**	**Process Time (min)**	**MLR**	**Rubbing Fastness**	**Washing Fastness**	**Heat loss (kJ)**
1	40	50	1:6	Yes	Yes	5553.41
2	40	60	1:6	Yes	Yes	5956.91
3	40	65	1:6	Yes	Yes	6510.91
4	50	50	1:6	No	No	5896.31
5	50	60	1:6	No	No	5593.91
6	50	65	1:6	No	No	6097.91
7	**60**	**50**	**1:6**	**No**	**No**	**5567.51**
8	60	60	1:6	No	No	6137.51
9	60	65	1:6	No	No	6364.51
10	70	50	1:6	Yes	Yes	5647.28
11	70	60	1:6	Yes	Yes	6075.68
12	70	65	1:6	Yes	Yes	6277.28

- **Result Table 6:**

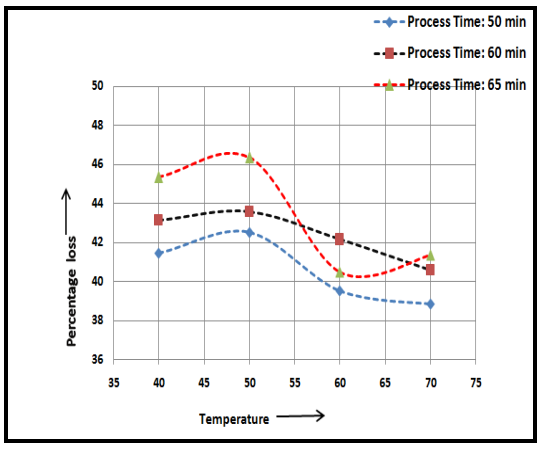
Heat Loss Assessment for Obtaining Quality Product after Dyeing for Constant Process Time, Varying Process Temperature and MLR

Sr. No	Process Time (min)	Process Temp (°C)	MLR	Rubbing Fastness	Washing Fastness	Heat loss (kJ)
1	50	40	1:6	Yes	Yes	6762.19
2	50	40	1:9	Yes	Yes	9917.91
3	50	40	1:12	Yes	Yes	4056.63
4	50	52	1:6	No	No	6580.03
5	50	52	1:9	No	No	9899.70
6	50	52	1:12	No	No	3713.30
7	**50**	**64**	**1:6**	**No**	**No**	**5624.66**
8	50	64	1:9	No	No	10108.28
9	50	64	1:12	No	No	3596.76
10	50	76	1:6	Yes	Yes	5718.90
11	50	76	1:9	Yes	Yes	10266.47
12	50	76	1:12	Yes	Yes	3427.83
13	50	88	1:6	Yes	Yes	6235.13
14	50	88	1:9	Yes	Yes	10046.65
15	50	88	1:12	Yes	Yes	2884.90

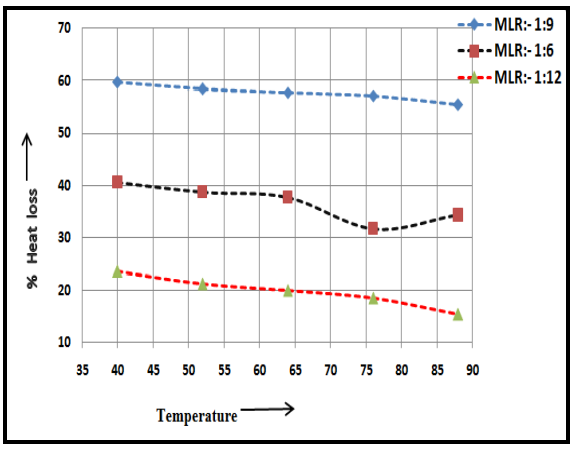
*__Yes__ - Indicates transfer of its colorants to adjacent white material

*__No__ - Indicates there is no transfer of colorants to adjacent white material

- **Summary of the Significant Results Obtained So far:**



Graph 1: Percentage Heat Loss Vs Temperature for Constant MLR



Graph 2: Percentage Heat Loss Vs Temperature for Constant Process Time

CONCLUSIONS:

As the principal objective of research work is to optimize the energy consumption used in textile dyeing process. Numbers of experiments were performed under the assistance of shift supervisor in research Industry by taking into account various parameters like,

i) Dyeing Process Temperature
ii) Dying Process Time
iii) Mass to Liquor Ratio (MLR)

Analysis has been carried out for heat consumption and it was found that dyeing process parameters have the significant influence on the heat consumption.

From the analysis conducted, the heat consumption during dyeing process is more than the heat required. It is also found that there is minimum heat loss for the following optimized values of process parameters.

The heat loss for dyeing process **with previous process parameters is 6363.88 kJ**					
The heat loss for dyeing process with **modified process parameters** is as follows					
Case I: For Constant MLR, Varying Process Temperature and Process Time					
Sr. No.	Optimized Values of Process Parameters			Total Heat Loss (kJ)	Energy Saving (kJ)
	Time	Temperature	MLR		
1	50 min	60°C	1:6	5567.51	796.7
Case II: For Constant Process Time, Varying Process Temperature and MLR					
2	50 min	64°C	1:6	5624.66	739.22

With this optimized process parameters following characteristics/properties were maintained,

i) No mixing of colours.
ii) Mechanical strength of thread remains constant.
iii) Achieved same life of thread.
iv) Overall quality of thread is maintained.
v) Energy saving carried out.

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