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Energy Optimization in Dyeing Process By Using Controlled Parameters

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ABSTRACT: A detailed study was conducted for small the scale textile industry in depth for the various processes involved, chemicals required, raw material and equipment details, operating parameters, energy requirements during processes including different losses etc. and to optimize thermal energy requirements in order to achieve acceptable good quality of cotton coloured products. In Indian dye (textile) industry, the major factors affecting regarding energy consumption. In addition, some technical information's has been included with schematics processes used for production as also machineries.

KEYWORDS*:* Textile, Dyeing, Thermal Energy, Optimization, Materials, Processes.

I. INTRODUCTION

Current position of small scale textile industry in India:
India earns about 27% of its total foreign exchange through textile exports and contributes nearly 14% of the total industrial production of the country. Indian textile industry is the largest in the country in terms of employment generation; currently it generates employment more than 35 million people. It is also estimated that the industry will generate 12 million new jobs by the year 2014.

World's total textile demand and production base distribution:
World population will grow from the present 5.4 billion to 10 billion in 2050, and further to 11.6 billion in 2150 when it is expected to reach a steady state. The total textile consumption forecast is going to double, even using the current figure of per capita annual average textile consumption (8kg/person).[2]

Processes used in Small Scale Textile Industries:
Figure 1 revels the flowchart for textile processing.
Raw material Supply: **Natural fibers** may be organic or inorganic in nature. **Man-made fibers** are broadly classified as organic regenerated natural fibers
Yarn preparation: The preparation for spinning of raw material components into consistent and continuous fiber filaments (i.e. thread or yarn). The production of continuous fiber is hand or machine processed

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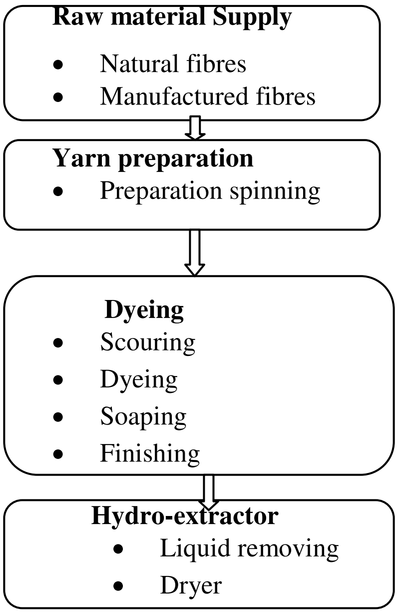

Fig.1: Schematic diagram of textile processing

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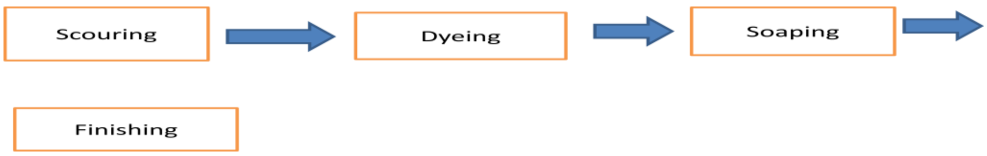

Fig.2: Flow diagram for dyeing process

Figure 2 shows the flow chart 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. Scouring is done at 90-110^{0}C.

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.

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.[4][6]

There are different analysis techniques of optimization such as

1. Fuzzy decision system a) similarity analysis b) Decision analysis
2. Cluster analysis. 3. Soft computing techniques
4 Generic Algorithm 5. Fuzzy logic control
6. Pinch analysis 7. Stochastic mechanics approaches

Pinch technology is simple methodology of systematically analyzing chemical processes and the surrounding utility systems with the help of first and second law of thermodynamics. The first law provides the energy equation for calculating enthalpy changes (H) and the second law determines the direction of heat flow that is heat energy may only flow in the direction of hot to cold.

The objective of pinch analysis is to achieve energy savings by better process heat integration (maximizing process to process heat recovery and reducing external utility loads). It is applied to solve a wide range of problems in main stream chemical engineering. Wherever heating and cooling of process materials takes place, there is a potential

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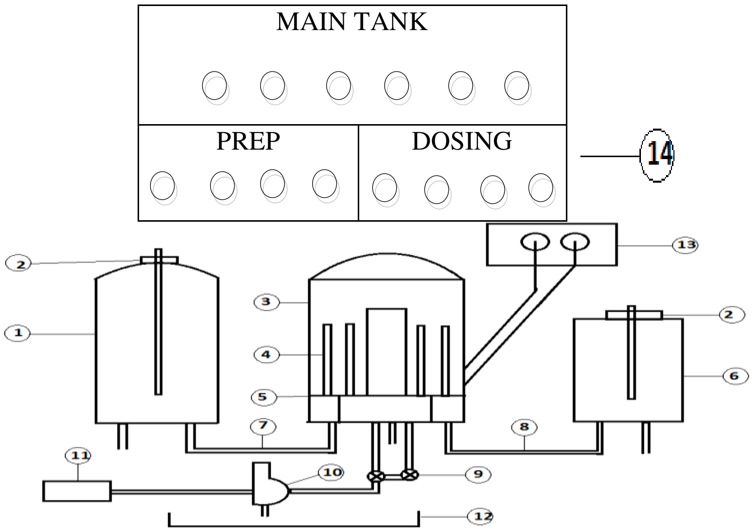
opportunity. This technology is used in projects relating to energy saving in industries such as iron and steel , food and drink , textiles ,paper and cardboards , cements , base chemicals, oil and petrochemicals.

Bench Scale Experimental Results:
The optimization of variable parameters in dyeing process were conducted on bench scale unit as shown in Fig.3 and the block diagram for the same is depicted in Fig.4. The variable identified for the energy optimizations were temperature of dyeing process, time for dyeing process and consistency in the dyeing (water quantity, chemicals used for processing, quality and concentration of the dye etc.). The observations and results presented in Table No. 1 to ----.

Fig3: 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

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

II. LITERATURE REVIEW

Dr. Nasir Mukhtar Gatawa and Prof. C. U. Aliyu (2013) [1] 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

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Prof. Tanaji Dabade and Dr. Shivaji Gawade (2012) [2] 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.

Khalil Elahee (2011) [3] Described the techniques and technologies of heat recovery from waste water and exhaust air are analyzed. 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.
Ali Hasanbeigi (2010) [4] 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.

Mr. S. Ashok (2010) [5] presented that electricity consumption is increasing in Textile mills, due to prolonged use of the equipments in inefficient operating parameters. So focus area now is Energy consumption @ load end and by optimizing the energy usage of textile machines, we can have multiple benefits of less units per kg of yarn and health of machines enhance.

Ahmet Cay (2009) [6] 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.
Nahed S. E. Ahmed (2009) [7] described that the textile coloration is a wet process that uses dyes, chemicals, and large volume of water. The driving force being the need for cleaner, cost-effective, and value-added textile products. This review will provide a summary of recent developments in the coloration of textile fiber. Emphasis will be paid to the new technologies, in particular those based on physicochemical means such as nanotechnology, electrochemistry, supercritical carbon dioxide coloration, plasma, ultrasonic and microwave, and their uses in the coloration of textile fibers.

Rajakumari et al., 2008 [8] have invented and studied inputs for treating textile waste water using pretreatment, 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.

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

Reading No.1		Shade-Black	Wt-0.980Kg	* MLR-1:6	
Time in	Time out	Process time	Name of process	Particulars	Process temp.(ºC)
10:00	10:25	30min	Scouring	To obtain Temp of 90 ºC	
10:25	10:45	20min		Holding mixture of L.F+water	90
10:50	11:05	15min		To obtain Temp of 80 ºC	
11:05	11:15	10min		Holding in main tank	80
11:20	11:40	20min		Hold acid+water in M.T.	35
11:50	12:05	15min		Holding RLA & CA in main tank	35
12:05	12:15	10min		mixing of color in P.T.	35

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12:15	12:35	20min	Dyeing	Holding color in M.T.	35
12:53	12:45	10min		Mixing salt in P.T.	35
12:45	1:05	20min		Holding mixture (salt + color)	35
1:05	1:17	20min		obtain temp mixture to 60 ºC	60
1:17	1:47	30min		Holding mixture in main tank	60
1:47	2:07	20min		soda dosing from D.T.	60
2:07	2:22	10min		caustic dosing	60
2:22	3:27	65min		Holding the mixture	60
3:30	3:40	10min		Cold wash	35
3:40	4:00	20min		Acid wash	35
4:05	4:22	20min		obtain temp 90 ºC	
4:22	4:42	20min		Holding mixture (saracol+water)	90
4:45	5:00	15min		obtain temp 80 ºC	
5:00	5:10	10min		Hot wash	80
5:17	5:32	15min	Soaping	Acid wash	35
5:35	5:50	15min		obtain temp of 80	
5:50	6:00	10min		Holding in M.T.	80
6:02	6:17	15min		obtain temp of 80 ºC	
6:17	6:27	10min		Hold in M.T.	80
6:30	6:35	5min		Add 6069 ,210 ,acid , C.A	
6:35	6:45	10min	Finishing	To obtain temp.50 ºC	50
6:45	7:15	30min		Holding in main tank	50

* MLR- Mass of Cotton to Liquor ratio

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

Shade-BLACK	Wt-0.980kg	MLR-1:6									
Particulars	Device	Quantity	Total mass	Cp	Temp In	Temp Out	ΔT	MCpΔT	Total Process time	Heat from coil	Total heat
Unit		Kg	Kg	KJ/Kg K	K	K	K		hr	KJ/sec	KJ
Cotton		0.98	0.98	1.339	308	363	55	72.2098			
Water		1:06	6	4.186	308	363	55	1381.38			
L.F	Main Tank	1%	0.01	4.186	308	363	55	2.3023			
							0	1455.89	0.83		
Water in M.T	M T	1:06	6	4.186	308	353	45	1130.22			
Cotton	M T	0.98	0.98	1.339	363	353	-10	-13.1291			
								1117.09	0.41		
							Total	**2572.98**	**1.24**	**0.7**	**3124.8**

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

Particulars	Device	Quantity	total mass	sp.heat	Temp. In	Temp.Out	ΔT	MCpΔT	Total process time	Heat from coil	total heat
Unit		Kg	Kg	KJ/KgK	K	K	K	KJ	hrs	KJ/sec	KJ
RLA	M.T	0.5GPL	0.003	4.186	308	333	25	0.31395			
CA		1GPL	0.006	4.186	308	333	25	0.6279			
0.192% Yellow MER		0.19%	0.001882	4.186	308	333	25	0.196951			
0.084% RED MEBL		0.08%	0.000823	4.186	308	333	25	0.086127			
4.43% Black WNN		4.43%	0.043	4.186	308	333	25	4.49995			
Salt		80GPL	0.48	4.186	308	333	25	50.232			
Caustic		1GPL	0.006	4.186	308	333	25	0.6279			
Soda		5GPL	0.03	4.186	308	333	25	3.1395			
Cotton		0.980Kg	0.98	1.3397	308	333	25	32.82265			
Water		1:06	6	4.186	308	333	25	627.9			
								720.4469	**2.5**	**0.7**	**6300**

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

Mass Analysis											
Particulers	Device	Quantity	Total mass	Cp	Temp In	Temp Out	ΔT	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	4.19	308	363	55	1.38138			
Cotton		0.98	0.98	1.34	308	363	55	72.2098			
Water		1:06	6	4.19	308	363	55	1381.38			
								1454.97	0.6	0.7	1537.2
Cotton	M.T	0.980kg	0.98	1.34	363	353	-10	-13.129			
Water in M.T	M.T	1:06	6	4.19	308	363	55	1381.38			
								1368.25	0.4	0.7	1033.2
Cotton	M.T	0.980kg	0.98	1.34	308	353	45	59.0808			
Water in M.T	M.T	1:06	6	4.19	308	353	45	1130.22			
								1189.3	0.4	0.7	1033.2
Cotton	M.T	0.980kg	0.98	1.34	353	353	0	0			

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Water in M.T	M.T	1:06	6	4.19	308	353	45	1130.22			
								1130.22	**0.4**	**0.7**	**1033.2**

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

Mass Analysis											
Particulers	Device	Quantity	Total mass	Cp	Temp In	Temp Out	ΔT	MCpΔT	Total process time	Heat from coil	Total heat
Unit		Kg	Kg	KJ/KgK	K	K	K	KJ	Hrs	KJ/sec	KJ
210		2%	0.02	4.186	308	323	15	1.2558			
6069		3%	0.0245	4.186	308	323	15	1.538355			
CA	M.T	0.20%	0.002	4.186	308	323	15	0.12558			
Cotton		0.98	0.98	1.3397	308	323	15	19.69359			
Water		1:06	6	4.186	308	323	15	376.74			
A.Acid		0.30%	0.0025	4.186	308	323	15	0.153836			
								399.5072	**0.66**	**0.7**	**1663**

Table No.6: Effect of changing parameters on heat consumption during dyeing process.

Shade- Black		Wt- 0.980Kg	MLR-1:6		
Time in	Time out	Process time	Name of process	Particulars	Process temp.(ºC)
9:00	9:30	30min	Scouring	To obtain Temp of 90 ºC	
9:30	9:50	20min		Holding mixture of L.F+water	90
9:55	10:10	15min		To obtain Temp of 80 ºC	
10:10	10:20	10min		Holding in main tank	80
10:24	10:44	20min		Hold acid+water in M.T.	35
10:50	11:05	15min		Holding RLA & CA in main tank	35
11:05	11:15	10min		mixing of color in P.T.	35
11:15	11:35	20min	Dyeing	Holding color in M.T.	35
11:35	11:45	10min		Mixing salt in P.T.	35
11:45	12:05	20min		Holding mixture (salt + color)	40
12:05	12:17	12min		obtain temp mixture to 40 ºC	40
12:17	12:47	30min		Holding mixture in main tank	40
12:47	1:07	20min		soda dosing from D.T.	40
1:07	1:22	15min		caustic dosing	40
1:22	2:12	50min		Holding the mixture	40

2:15	2:25	10min		Cold wash	35
2:30	2:50	20min		Acid wash	35
2:55	3:12	17min		obtain temp 90 °C	
3:12	3:32	20min		Holding mixture (saracol+water	90
3:35	3:50	15min		obtain temp 80 °C	
3:50	4:00	10min		Hot wash	80
4:05	4:20	15min	Soaping	Acid wash	35
4:20	4:35	15min		obtain temp of 80	
4:35	4:45	10min		Holding in M.T.	80
4:45	5:00	15min		obtain temp of 80 °C	
5:00	5:10	10min		Hold in M.T.	80
5:15	5:20	5min		Add 6069 ,210 ,acid , C.A	
5:20	5:30	10min	Finishing	To obtain temp.50 °C	50
5:30	6:00	30min		Holding in main tank	50

Table No.7: Heat consumption during dyeing process due to change in parameters

Mass Analysis											
Particulers	Device	Quantity	Total mass	Cp	Temp In	Temp Out	ΔT	MCpΔT	Total process time	Heat from coil	Total heat
Unit		Kg	Kg	KJ/Kg K	K	K	K	KJ	Hrs	KJ/sec	KJ
RLA	M.T	0.5GPL	0.003	4.186	308	313	5	0.06279			
CA		1GPL	0.006	4.186	308	313	5	0.12558			
0.192%Yellow MER		0.19%	0.001882	4.186	308	313	5	0.03939			
0.084%RED MEBL		0.08%	0.000823	4.186	308	313	5	0.017225			
4.43%Black WNN		4.43%	0.043	4.186	308	313	5	0.89999			
Salt		80GPL	0.48	4.186	308	313	5	10.0464			
Caustic		1GPL	0.006	4.186	308	313	5	0.12558			
Soda		5GPL	0.03	4.186	308	313	5	0.6279			
Cotton		0.980Kg	0.98	1.34	308	313	5	6.56453			
Water		1:06	6	4.186	308	313	5	125.58			
								144.0894	**1.95**	**0.7**	**4914**

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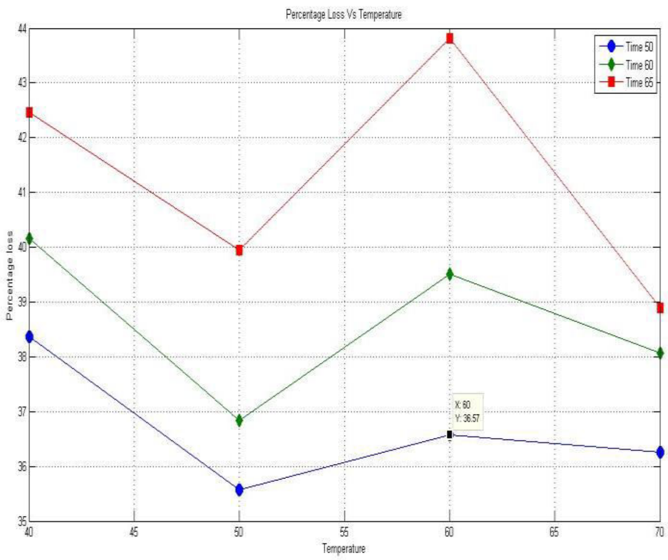
III. RESULT

Sr. No.	Processes	Total Heat Required	Total Supplied Heat
1	**Scouring**	2572.983	2187.36
2	**Dyeing**	144	4914
3	**Soaping**	5142.743	4636.8
4	**Finishing**	399.5072	1663.8
Total		**8259.3172**	**13402**
Total heat loss =		**5142.643**	
% heat loss =		**38.37%**	

Based on large number experiments conducted on bench scale unit, thermal analysis for optimized operating parameters for various operations are carried out through 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 of percentage heat loss Vs temperature at various time as shown in Fig. Optimum point was determined at 60^0 C and 50 min of dyeing process. The percentage heat loss at that point is 36.57%.



Graph1: Percentage heat loss Vs temperature at various time

Quality confirmation at optimized parameters for dyeing process:

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

Light fastness of many natural dyes, particularly which are extracted from flower petals are found to be poor to medium. So an extensive work has been carried out to improve the light fastness properties of different natural dyed textile. Most

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of the natural dyes have poor light stability as compared to the best available synthetic dyes and hence the colors in museum textile are often different from their original color.
Duff studied the light fastness and wash fastness under the standard condition (50ºC) and also 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 color 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 proper combination of fiber-mordant to achieve best color fastness.
Keeping the dyeing quality in view, particularly rubbing and washing and the results obtained are presented in the Table No.8.

Table No. 8 Heat loss assessment for obtaining quality product after dyeing

Temp (^{0}C)	Time (min)	Rubbing Fastness	Washing Fastness	Heat loss (KJ)
40	50	Yes*	Yes	5142.643
40	60	Yes	Yes	5545.247
40	65	Yes	Yes	6099.627
50	60	No**	No	4983.85
50	50	No	No	4681.459
50	65	No	No	5685.69
60	**50**	**No**	**No**	**5095.12**
60	60	No	No	5724.88
60	65	No	No	6889.12
70	50	Yes	Yes	5271.267
70	60	Yes	Yes	5699.667
70	65	Yes	Yes	5901.207

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

IV. CONCLUSION

The objective was to optimize the process parameters and experiments were conducted by varying different parameters such as temperature, time, etc. A mathematical calculations have been carried out for heat consumption. It is found that process parameters 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. The heat consumption for the process with exiting practices that are followed in the small scale industries is of the order of 6900 KJ and the heat consumption after optimization reduces to around 5100 KJ and percentage thermal energy saving is to the tune of 24%. 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.

V. ACKNOWLEDGEMENT

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REFERENCES

[1] Dr. Nasir Mukhtar Gatawa and Prof. C. U. Aliyu, "Impact of globalisation on textile industries: A case study of some nigerian industries in kano metropolis" EconomicsUsmanu Danfodiyo University, Sokoto, 2013.

[2] Tanaji Dabade, Dr. Shivaji Gawade and Prof. Balaji Khune, "Solapur textile industry an overview on marketing and financial problems" zenith International Journal of Multidisciplinary Research Vol.2 Issue 5, ISSN 2231 5780, May 2012.

[3] Khalil Elahee, "Heat recovery in the textile dyeing and finishing industry: lessons from developing economies" University of Mauritius, 2011.

[4] Mr. S. Ashok, Coimbotor, "Energy-Efficiency Improvement Opportunities for the Textile Industry" Ali Hasanbeigi , China Energy Group, Energy Analysis Department, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, 2010.

[5] Prof. Y. M. Indi, 2009, "Process control and safety in chemical processing", Process control and safety in chemical processing of textiles, 2009.

[6] Ahmet Cay a, Is_ık Tarakcıog˘lu a, Arif Hepbasli b, "Assessment of finishing processes by exhaustion principle for textile fabrics: An energetic approach" Applied Thermal Engineering 29 , 2554–256, 2009.

[7] Nahed S. E. Ahmed, Reda M. El-Shishtawy, "The use of new technologies in coloration of textile fibers" Springer Science+Business Media, LLC 2009, December 2009.

[8] S Priscilla Rajakumari and S Kanmani, "Environmental life cycle assessment of zero liquid discharge treatment technologies for textile industries, Triupur- A case study", Journal of scientific and Industrial Research, Vol 67. PP461-467, June 2008.

[9] T. Markis a, J.A. Paravantis b, "Energy conservation in small enterprises" a University of Ioannina, Ioannina, Greece, b University of Piraeus, Department of Technology Education and Digital Systems, 185 34 Piraeus, Greece, August 2006.

[10] Harun Kemal Ozturk, "Energy usage and cost in textile industry: A case study for Turkey" Pamukkale University, Turkey, January 2004.