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Potentiality of Compact Yarn in Knit Dyeing for Cleaner Production

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Abstract— Water, steam, electricity and chemical minimization studies were carried out in a textile mill employing cotton fabric knitting and subsequently dyeing-finishing by approaching to compact yarn. Detailed onsite investigations and analysis on production processes were performed according to UNFCC clean Development Mechanism (CDM) promotion. Specific consumptions in wet processes were calculated by mass balance analyses. Water samples were collected and various parameters were analyzed. The multi-criteria decision-making methods were employed to determine suitable best available techniques. Feasibility analysis was performed and potential benefits and savings were determined for both suggested technique. After the study it come to front that, use of compact yarn shows effective outcome against use of bio polish which can lead process optimization as well as can save enormous amount of water, energy and contribute to reduce the carbon footprint. It is possible for manufacturer's to reduce their water, steam, electricity & carbon footprint through environmental friendly technology practices. The overall costs can be reduce as much as 20 ~ 30 % or more by implementing no-cost and clean production technique. Furthermore, overall savings can be doubled or tripled when the associated saving in raw materials is taken into account.

Index Terms— Compact yarn, Bio-polish, Utility waste, CO_2 emission, Knit dyeing

1 Introduction

The textile manufacturing process is consumes high amount of resources like water, steam, electricity and a variety of chemicals in a long process sequence. The common practices of low process efficiency result in substantial wastage of resources and a severe damage to the environment [1]. Industrial activities thus polluting the limiting source of energies.

The global water demand is expected to be 1500 billion m3 according to average economic growth scenario 2030 [2]. Which brings the questing of avoiding the wastage of water, unless the world on behalf of avoiding global fresh water crisis in the future. Different tactics that upkeep the sustainable use of natural resources and sustainable production processes have been developed in the last 20-30 years [3]. Cleaner production is one of them, which defines the protection of resources and environment as a whole with an integrated approach [4]. Cleaner production is to avoid the wastages of natural resources and be aware of discharge such waste which may pollute the natural substances. Cleaner production is also referred as a proactive environmental protection strategy [5]. Besides, cleaner production in the industrial enterprises may rovide reduced production costs, improved competitiveness to meet the requirements of existing and future regulation or standards [6]. Water is one of the most significant inputs of wet processes in textile industry. The specific water consumption is reported to range 3-932 L/kg product depending on fiber type, applied techniques and technologies [7, 8]. Different investigation showed that, specific water consumption ranges from 10 to 645 L/kg product (average 22-184) in the textile industry and such values are 21-645 L/kg product (average 92-162) in mills employing cotton fabric finishing-dyeing [9]. Textile production processes are characterized by their comparatively high specific chemical consumption. Chemical consumption is about 10-100% in proportion to total fiber weight in textile processing [10]. A large number of chemicals are needed to impart the desired properties to textile fibers such as acids, bases, surfactants, enzymes, stabilizers, dispersing agents, retarders, salts, dyes, solvents, emulsifiers and fixing agents [11]. Literature indicated that chemical consumption could be reduced 20-50% by the implementation of various measures of cleaner production techniques in the textile industry [12].

The application of enzymes in textile processing started in the middle of 19th century when malt extract was used for desizing of some textiles [13, 14]. Later it becomes popular method of textile processing. But its negative effect was not taken onto consideration. A large number of process loss happened in this step. In this study, onsite cleaner production assessment study was carried out by a sustainable solution of reduce the wastage of water and chemicals by avoiding not necessary bio polishing. With a systematic approach, this research investigated this sustainable solution of avoiding bio polish by using compact yarn. The employed unique methodology and the findings of this study (i.e., potential reductions in water, steam, electricity and chemical usages and potential savings) will be useful to similar textile mills, stakeholders and regulators. The structure of this study may provide a road map to textile industry for their cleaner production applications.

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2 EXPERIMENTAL

2.1 Materials

For this experiment 180 GSM single jersey cotton fabric was taken. Fabric was knitted from compact yarn having following characteristics given in the table 1. Hairiness and imperfection index (IPI) was calculated 4.55 and 39 respectively. Common chemicals and auxiliaries was collected from the company's regular stock.

TABLE 1: USTER® report of 30/1 Low TPI Compact Yarn

Nr.	U%	CVm	CVm 1 m	CVm 10 m	Thin -50%
Unit	%	%	%	%	/km
1	9.22	11.69	3.37	1.82	0.00
2	9.24	11.62	3.40	1.52	0.00
3	9.50	11.99	3.92	3.00	0.00
4	9.32	11.82	3.92	2.71	0.00
5	9.28	11.69	3.61	2.32	0.00
Mean	9.31	11.76	3.64	2.27	0.00

Nr.	Thick +50%	Neps +200%	sh	H	Rel. Cnt ±
	/km	/km			%
1	10.00	20.00	1.08	4.57	0.40
2	10.00	15.00	1.03	4.44	-0.20
3	40.00	25.00	1.03	4.50	-0.50
4	25.00	25.00	1.09	4.65	0.40
5	5.00	20.00	1.06	4.61	-0.20
Mean	18.00	21.00	1.06	4.55	0.00

From our findings the best quality yarn can be sourced by following setting main parameter given in Table 2.

TABLE 2: Parameters Limit Value for 30/1 Ne Parameters

Parameters	**Limit Value for 30/1 Ne**
Uster %	< 10 %
TPI (Twist per Inch)	16 to 19
Thin/Km (-50%)	0
Thick/Km (+50%)	< 20
Neps/Km (+200%)	< 25
Total Imperfection or Imperfection Index.	< 45
Hairiness	< 6
CSP (Count Strength Product)	2300 ~ 2500

2.2 Processing Equipment's

Schlavos (Athena 2) dyeing machine having capacity per nozzle of 250 kg, Nozzle pressure of 4-6 psi, Steam pressure of 7 bar (inlet of heat exchanger) , Cold water temp. & pressure of 25 c & 3 bar, Maximum temperature of 142°C, Reel/Winch speed of 150-420 rpm, Main motor efficiency of 80-95% was used for bulk experiment. Datacolor 650 Spectrophotometer was used to measure the exhaustion and fixation of dyestuffs. Water, steam and electricity flow meter was installed with the dyeing machines thus gives electronic data regarding the usage of utilities. Electric balance and spoon were used to weigh the dyestuffs and chemicals.

2.3 Methods

In this study, minimization of water and chemical consumptions were taken as a priority considering avoiding of use of bio polish treatment and reduction of use of water, steam, electricity for cleaner production. First of all in this research, investigation of existing process flow, data collection of utilities and chemical consumptions, identification of inefficiencies were carried out. On-site investigations were performed and water/chemical consumptions of the production processes were evaluated. After that, mass-balance calculations were conducted for the production processes based on specific inputs and outputs. Specific water and chemical consumptions were calculated. It should be noted that the production schedules and dyeing recipes in the studied mill may vary over time in terms of fashion trends and customer orders. To compensate these variations and capture the general performance of the mill, continuous data was used. Finally in this research, the multi-criteria decision methods were used to quantitavely evaluate the use of compact yarn to avoid bio polishing. Multi-criteria decision-making is an effective approach that can be successfully used for revealing eco-innovative solutions [15].

2.4 Studied Textile Mill

This research were carried out in a knit fabric processing industry. Annual fabric pretreatment and dyeing capacities of the mill were 1450 and 6100 tons/year, respectively. Water demand of the mill was supplied from groundwater resources and raw water demand of the mill was approximately 3200 tons/day. Raw water has considerable hardness content due to the geological structure of the region. Raw water was softened by cationic ion exchange resins to be used mainly as process water in wet processes. Other uses of softened water were for regeneration of ion exchange resins and partly for steam generation. Some fraction of the softened process water was further treated by reverse osmosis (RO) to provide demineralized water to be used in steam boilers. Thus, steam generation performance was increased and possible inorganic scaling and/or corrosion problems in hot pipes and boilers were proactively avoided. A very small portion of the raw groundwater was directly (without softening) used in facility cleanings.

Large volume of wastewater was generated in the mill mainly due to the intensive water consumption in wet processes. The main sources of wastewaters in the mill were wet processes, regeneration of ion exchange resins, facility cleaning operations, RO concentrates, and domestic usage. During the study, the average combined/composite wastewater flowrate (industrial and domestic) of the mill was 2752 m3/day. Wastewater streams from various production processes were collected

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through a combined channel system. The combined wastewater was sent to a common industrial wastewater treatment plant (conventional anaerobic biological treatment) in the organized industrial region.

3. Results and Discussions

3.1 Existing process analysis

Most of the common Textile and Garments factory use very low quality Carded and combed yarn and later on they make a cosmetic surgery named Enzyme wash or bio polishing. Yarn is the foundation of fabrics. The Enzyme wash remove the hairiness and neps from the fabric surface gives a better outlook. If we can use compact yarn then we can easily avoid the Enzyme wash or bio polishing. Table 3 and Table 4 shows the existing utility consumption, processing time, process loss% and CO2 emission for one kg cotton knitted fabric. The water consumption for processing one kg of knitted fabric lies between 40 liter to 140 liter based on type and depth of shade. The lowest water consumption comes for white and highest for turquoise dark shade.

TABLE 3: Existing Utility consumption analysis (With bio polish)

Shade name	Water (liter/kg)	Steam (kg/kg)	Electricity (kwh/kg)
Light	70-80	7.0-7.5	0.40-0.50
Medium	80-90	7.0-8.0	0.45-0.55
Dark	90-110	8.0-8.5	0.45-0.55
Black	90-120	9.0-10	0.50-0.60
White	40-60	5.0-6.0	0.35-0.50
Turquoise-light	80-100	8.0-9.0	0.45-0.55
Turquoise-medium	90-120	8.0-9.5	0.45-0.60
Turquoise-dark	100-140	9.0-11	0.55-0.70

TABLE 4: Existing Time, process loss% and CO2 emission analysis (With bio polish)

Shade name	Time (hrs.) /batch	Process Loss %	CO_2 emission (kg/kg)
Light	08-10	12-14	0.8-1.0
Medium	09-11	11-13	0.9-1.0
Dark	10-12	11-13	0.9-1.1
Black	10-13	12-13	0.9-1.2
White	07-08	07-09	0.7-0.9
Turquoise-light	11-13	12-14	0.8-1.0
Turquoise-medium	12-14	12-14	0.9-1.2
Turquoise-dark	13-16	13-15	1.0-1.3

To process one kg of knitted fabric for light shade required 7.0 kg to 7.50 kg of steam and for black and turquois shade it's around 9 to 11 kg. According to shade type 0.15 kwh to 0.50 kwh electricity required for process one kg knitted fabric under existing techniques where 7 hours to 16 hours of time required. Process loss percentage for white shade found 7 to 8 percentage which is lowest among all and 13 to 14 percent found for turquoise black shade. The CO2 emission of all types of shade has not far difference. The lowest CO2 emitted by white color processing and highest for all dark and turquoise medium shade. The use of new generation Dye stuff and process optimization can save enormous amount of water, energy and contribute to reduce the carbon footprint. This method can save money which can easily cover the extra cost of compact yarn.

3.2 Process sequence of Dyeing followed by bio-polishing

Scoured & Bleaching
↓
Cold wash
↓
Bio-polishing
↓
Enzyme Killing
↓
Cold wash
↓
Dying
↓
Cold wash
↓
Hot wash
↓
Soaping
↓
Hot Wash
↓
Cold wash
↓
Softner

3.3 Effect of using Compact yarn for cleaner production

Cosmetic treatment of yarn is an additional treatment for a dyeing industry. This treatment is performed to remove the hairiness of the yarn. Compact yarn has lowest hairiness in its surface than other yarns. Use of compact yarn in knitting later on avoid bio polishing in dyeing and finishing treatment. In this research, traditional carded and combed yarn has been replace by compact yarn to avoid bio polishing and, investigated it's the potentiality. Table 5 and Table 6 describes the consumption of water, stream, electricity as well as process loss and CO2 emission of novel concept.

TABLE 5: Utility consumption analysis (Without Bio polish)

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Shade name	Water (liter/kg)	Steam (kg/kg)	Electricity (kwh/kg)
Light	30-40	4.0-4.5	0.20-0.30
Medium	40-50	4.0-5.0	0.25-0.35
Dark	45-60	5.0-5.5	0.25-0.35
Black	50-60	6.0-7.0	0.30-0.40
White	20-30	2.0-3.0	0.15-0.20
Turquoise-light	60-75	5.0-6.0	0.25-0.35
Turquoise-medium	60-80	5.0-6.0	0.25-0.40
Turquoise-dark	70-100	6.0-7.0	0.35-0.50

TABLE 6: Existing Time, process loss% and CO2 emission analysis (Without bio polish)

Shade name	Time (hrs.) /batch	Process Loss %	CO_2 emission (kg/kg)
Light	06-08	07-08	0.6-0.8
Medium	07-09	07-09	0.6-0.8
Dark	08-10	08-09	0.6-0.9
Black	09-10	08-09	0.6-0.9
White	05-06	06-07	0.6-0.7
Turquoise-light	08-09	07-08	0.6-0.8
Turquoise-medium	08-10	08-10	0.6-0.9
Turquoise-dark	09-10	09-10	0.6-0.9

By comparative study of table 3,4 and table 5,6 is has been clearly seen that, avoiding bio polishing it can be avoid 30% of utility consumption, can save 12% of production time and reduce around 28% average process loss. This change also able to reduce CO2 emission at a considerable value thus make this change sustainable.

3.4 Cost saving analysis of using compact yarn

Several trials have been conducted to avoid bio polish in knit dyeing process & found that factory could able to reduce their water, steam, electricity & process time consumption and at the same time reducing cost. For a 1000 Kgs of knitted fabric cost analysis is investigated. Table 7 shows the unit price of utilities is based on current global price.

TABLE 7: unit price of utilities is based on current global price

Types	Unit price
Electricity price	57.69 USD/Mwh.
Water cost	0.064 USD/m^3
Steam price	4.79 USD/Ton.
Depreciation cost (for 1000 kgs machine)	0.205 USD/hrs.
Conventional yarn price	3.30 USD/Kg (30s Ne).
Good quality yarn price	3.50 USD/Kg (30s Ne).
Wastewater treatment cost	0.102 USD/Cubic meter

3.5 Saving of avoid bio polish

Bio polish of enzyme treatment involves at least three steps in coloration process. This three steps includes, enzyme treatment at the temperature of 55°C to 60°C for about 60 mins in a pH of 4.5 to 5.5, then its requires killing the enzymes at temperature of 75°C to 80°C for 10 minutes to 15 minutes, after that a rinse wash. All the steps consumes enormous amount of water, steam, electricity and time. This process also causes for the increase the process loss cost, waste water treatment cost, chemical cost and depreciation cost at a considerable level. After comprehensive investigation on additional cost of bio polish under global price of utilities given in the table 7 it can be stated that, by avoiding bio polish these additional costs for this cosmetic treatment can be saved. Table 8 shows the saving of avoid bio polish by using high quality compact yarn for processing of 1000 kg of knitted fabric under exhaust dyeing method.

TABLE 6: Saving of avoid Bio polish for 1000 kgs of Knitted fabric

Type of cost	Value (USD per 1000 kgs)
Water	1.03
Steam cost	2.40
Electricity cost	1.73
Enzyme and chemical cost	60
Process loss cost	148.50
Waste water treatment cost	1.63
Depreciation cost	2.73

It can be seen that, by avoiding bio polish water can be saved which is cost around 1.03 USD for 1000 kg of fabric. This is not only a technical advancement but also has positive impact on environment. Besides avoiding bio polish about steam cost, electricity cost, chemical cost, process loss cost can be saved about 2.40 USD, 1.73 USD, 60 USD and 148.50 USD respectively. With the saving of water avoid bio polishing indirectly decrease the load of effluent and effluent treatment, this will save around 1.63 USD for 1000 kg of fabric. The process carried out in the production floor, thus use the machines and equipment. Avoiding bio polish will also save the depreciation cost of the equipment's. The minimum saving founds from depreciation cost from this technique is cost about 2.73 USD.

Saving of avoid bio polish of 1000 kgs knitted fabric = (Additional cost of Water + Additional Steam cost+ Additional Electricity cost + Additional Enzyme and chemical cost + Additional Process loss cost + Additional Waste water treatment cost + Additional Depreciation cost)

So, Total additional cost of bio polish procession of 1000 kgs knitted fabric = (1.03 + 2.40 + 1.73 + 60 + 148.5 + 1.63 + 2.73) USD

= 218 USD

Besides direct saving from water, steam, electricity, enzyme, chemicals, process loss, water treatment and depreciation cost, avoiding bio polish saves enormous amount of time, thus leads to increasing of productivity. After a comprehensive analysis it was found that by avoiding bio polish the production increase by 117 kg. This increase production saves the processing time and productivity worth about 71 USD for 1000 kgs of knitted fabric processing. So the total saving from avoiding bio polish is worth about 289 USD for 1000 kgs knitted fabric. To avoid bio polish additional cost will be additional cost of high quality yarn. According to the global price and unit price given in table 7; Additional cost of high quality yarn is 250 USD for 1000 kgs knitted fabric.

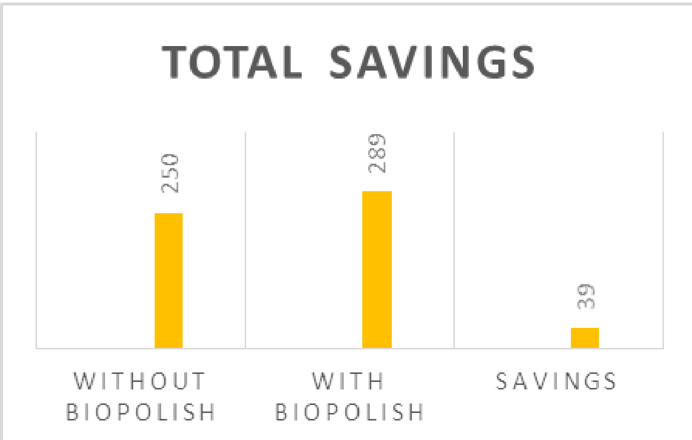

Figure 1: total saving by using compact yarn from 1000 kg fabric

By Arithmetic calculation of savings and cost of avoiding bio polish shows that, If factory use good quality yarn to avoid bio polishing, they can increase production 177 kg and make 39 USD profit from per 1000 kgs fabrics shown in figure 1.

4. CONCLUSION

In the age of industrialization, environmental pollution is a matter of great concern. CO2 emission and surface water pollution is one of the elements of this pollution. Surface water is the water we find in the river, canals, cultivation field and other water bodies on the earth. Severe pollution of this water is causing serious health hazard in the neighborhood, damaging fertility of the land, killing fishes and aquatic lives. On the other hand CO2 emission is a great threat for all living things. In this research, it has been tried to bring in the light that, use of water, steam, electricity and time can be save by a profitable change. Implementation of this technique can also lead to clean production.

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