Energy Management Opportunities in Dyehouses

B.Y.R Surnam

***Abstract*—** The textile industry is one of the pillars of the Mauritian economy. Presently, the textile sector is becoming increasingly competitive internationally due to trade liberalisation and erosion of trade preferences. To face these challenges, the textile mills are developing different strategies to decrease cost and improve efficiency. Energy management is one of them.

This paper, therefore, looks into the energy management opportunities in the dyehouses of the textile mills in Mauritius. Dyehouses normally consist of the dyeing and finishing sectors. Energy conservation measures that can be considered in the dyeing and finishing sectors in textile mills in general are discussed.

The dyeing process was found to consist of several processes whose temperature varies between 70^0C and 98^0C. Use of the waste water from these operations can be used to pre-heat the incoming fresh water. This would lead to lesser heating in the dyeing machines. Also, insulation of the dyeing machines can also lead to less energy loss and, consequently, less of heat input.

In finishing sector, stenters and dryers are the equipment which use very high air temperatures for their operation. The waste heat can be used to preheat the incoming air in these machines.

For the steam systems, in addition to efficient condensate recuperation, proper thermal lagging should be used in the pipe circuits. Solar water heaters can also be used to preheat feedwater make-up and hot water for dyeing purposes.

***Keywords*—**Dyeing, finishing, textile, waste energy

I. Introduction

THE Mauritian Industrial Revolution, in the 1980s, has been spearheaded by the textile industry. For the past four decades, the textile industry has acted as the engine of economic growth, attracting Foreign Direct Investment (FDI) from various countries, creating new employment opportunities, and strengthening the manufacturing base of the economy. It has started from a basic producer to a vertically integrated supplier of design-led garments, providing flexible solutions, in terms of price points, volumes and runs, to the specific needs of clients worldwide. For the year 2012, exports of "Articles of apparel and clothing accessories", represented 35.5% of our total exports. Some Mauritian manufacturers are even investing in other countries such as Madagascar and Bangladesh due to their relatively low labour cost.

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Mauritian manufacturers have the capability to supply a wide range of textile products, including, T-Shirts, lingerie & loungewear, shirts, sportswear, trousers & denim, kidswear, pullovers, uniforms and beachwear. Most of the clothing production in Mauritius is exported. In that respect only a few local producers, mainly small factories and the informal sector, produce for the local market. Traditionally, the main export markets for apparel have been Europe and the USA but since the last few years our exports to the South African market have been constantly increasing. In 2012, export to Europe accounted for 48 %, USA - 18 %, South Africa - 24 % and others 11% [1].

However, the international textile sector is becoming increasingly competitive due to trade liberalisation and erosion of trade preferences. To face these challenges, the textile mills are developing strategies consisting of technology upgrading, process re-engineering, development of clusters and linkages, promotion of SMEs into export-oriented enterprises, skills and human resource development, product and market diversification and regional integration. Energy management is another very important issue which is given due consideration by the textile mills.

It should be noted that a majority of the exported textile products consist of knitted fabrics. There are very few spinning and weaving mills in Mauritius. Most of the larger companies import yarns which are then knitted. Hence, this study considers the issue of energy management in the dyehouses of the Mauritian textile mills, with focus on knitted fabrics.).

Dyeing and finishing processes

Dyeing is the application of desired colour to the fabric whereas finishing involves a number of processes such as softener padding to impact on softness, drying to remove moisture, compacting/calendaring/stentering to impact on dimensional stability [2].

The dyeing process depends in several factors such as fabric state (tubular or open), colour and colour strength to be developed, the dyeing technology, the quantity of materials to be dyed and the quality requirements of the dyed fabrics. The finishing process depends on the end use of the fabrics and the customer requirements [2].

The exhaust dyeing process using softflow dyeing machines is the most popular and common method used for dying of knitted fabric [2]. Jet dyeing is now a mature technology and a very commonly used technique for dyeing of knitted fabrics in rope form. Fig. 1 shows a jet dyeing machine usually seen in Mauritian textile mills.

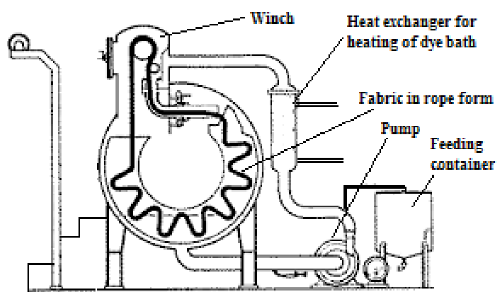

Fig. 1- Jet dyeing machine

The main features of the dyeing machine are:

- The fabric, which remains in rope form in the dyeing machine during the dyeing process, is circulated by means of the circulation pump and winch. The circulation pump circulates water round the water circuit and the dyeing machine. This produces a water jet at the nozzle which pulls down the fabric in the dyebath. The fabric is then pulled up by means of the winch.
- Heating and cooling of the dyebath is performed by the heat exchanger.
- Additions (chemical and dyestuffs) are added through the feeding container.

The dyeing procedure consists of many processes, for example bleaching, rinsing and dyeing, which needs the dyebath which needs to be at a high temperature (above 70^{0}C). Bleaching process that is performed prior to the dyeing process involves temperatures between 90^{0}C to 98^{0}C. During the dyeing process, temperatures can reach as high as 95^{0}C. For hot rinses, after the dyeing process, temperatures can vary between 70^{0}C to 90^{0}C. Other processes, such as softening, can be performed at lower temperatures of 40^{0}C.

The basic function of the finishing process is to give the fabric an aesthetic value where senses of sight and touch are involved and to an increased utility where qualities like shrinkage, crease resistance, etc can be controlled. It's basically the idea of making cloth more acceptable in a ighly competitive market. In the finishing section, common processes involve drying, stentering, calendaring and/or compacting. For the stentering process, which makes use of large amount of heated air, temperatures can go as high as 190^{0}C. The drying processes make use of lesser amount of air. The calendaring and the compacting processes normally make use of steam which is returned back to the steam system as condensate.

This study show the energy management opportunities in a dyehouse, with respect to the processes involved during dyeing and finishing of the textile fabrics. The data were collected from major dyehouses in Mauritius.

II. Methodology

Major dyehouses in Mauritius were considered for this study. The energy conservation measures related to the dyeing and finishing processes were considered taking into consideration the waste heat that could be recuperated or simply eliminated. The recommendations are followed from energy audits performed in various textile mills around the island.

III. Results and Discussion

A. The dyehouse

The dyeing process involves the use of high temperatures for bleaching, dyeing and hot rinsing. These hot temperatures can be provided by heating of the dye bath using steam, through a heat exchanger, in the dyeing machine. Some of the processes are performed at 40^{0}C while other processes, such as cold rinsing is performed at room temperature at around 20^{0}C. Heating of the dye bath from 25^{0}C to 70^{0}C and even up to 98^{0}C does not only lead to considerable use of energy but also the whole dyeing process takes more time because the temperature gradient for the heating process would be performed at 3^{0}C/min.

Under these circumstances, the heat from the high temperature discharge of the dyeing machines can be used to pre-heat the water to be used for the different processes in the dyeing machines.

A proper technique that can be used to make use of this waste heat is to have two different discharges- a high temperature and a low temperature one. The low temperature discharge, would be used to collect all the discharge from the dyeing machine and the dyehouse in general, including waste water from the squeezer or the hydro-extractor, which are at 20^{0}C to 40^{0}C and they would be released to the waste water drains. The high temperature discharge (or hot waste water) would consist of all waste water from the dyeing machine having a temperature of 70^{0}C to 98^{0}C. It can be used to pre-heat the fresh water from the water mains, through a heat exchanger, before it is used for the dyeing purposes. A hot water tank can be used for this purpose, to store the heated water (or hot water) as a buffer for use in the dying machines. A schematic diagram of the system is shown in Fig. 2.

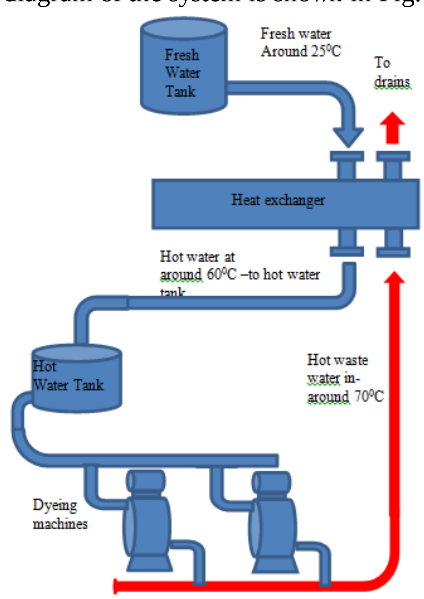

Fig. 2- Simple system showing use of hot waste water to pre-heat the fresh water

On average, through 24 hours and taking into consideration tha there are no significant changes in dyed fabric colour, the amount of hot waste water going into the heat exchanger would be equal to the amount of fresh water passing through it. Hence, taking into consideration the effectiveness of the heat exchanger, a hot water temperature of 60^0C can be expected.

The use of hot water, stored in a hot water buffer tank, for the dyeing processes can lead to considerable decrease in process time. Heat recuperation from the hot waste water can be very beneficial financially. An example of a reactive dyeing process that can be performed in the dyehouse, as shown in Table 1, is considered. The total duration of the dyeing process is 540 mins and the temperature gradient for heating is considered to be 3^0C/min. The softwater inlet to the dyeing machine consists of a mixing valve for cold and hot water. The use of fresh water at 20^0C for the process is compared to that when using hot water at 60^0C. The expected decrease in the duration time is determined.

TABLE I
DECREASE IN THE PROCESS TIME

No	Process	Process tempera-ture (^{0}C)	Soft water (20^0C) heating time, min	Soft water (60^0C) heating time, min
1	Pre-treatment	95	25	12
2	Acid treatment	60	13	0
3	Rinsing	20	0	0
4	Dyeing	50	10	0
5	Rinsing	50	10	0
6	Acid treatment	50	10	0
7	Rinsing	80	20	7
8	Soaping	95	25	12
9	Rinsing	80	20	7
10	Rinsing	50	10	0
11	Softening	40	7	0
	Total heating time		*150*	*38*

A substantial decrease in the duration of the dyeing process is observed.

Without the heat recovery system:

Process time (pre-treatment and dyeing) = 390 mins

Heat time = 150 mins

Time of machine occupation = 540 mins

With the heat recovery system:

Process time (pre-treatment and dyeing) = 390 mins

Heat time = 38 mins

Time of machine occupation = 428 mins

Savings in time = 112 mins

= 21%

21% savings in time is observed which is substantial and therefore use of the heat recovery system and its optimization is essential in textile mills.

Thermal insulation of the dyeing machines

Taking into consideration the high temperatures involved in the dyeing process, one method of considerable improving the energy efficiency of the dyeing process is by thermally insulating the dyeing machine. Table 2 shows some results of the significant decrease in the dyeing machines' surface temperatures measured after coating them with a thermally insulated coating.

TABLE II
TEMPERATURE OF THE SURFACE OF THE DYEING MACHINE

Temperature of the process (^{0}C)	**Surface temperature (^{0}C)**
80-95	60-65
60-70	45-55
50	40

B. *The finishing process*

After squeezing the excess water, the fabric is sent to the finishing section. The stentering process forms a major part of the finishing section. The stenter basically is used to dry the fabric, to apply finishing chemicals and to stabilize the fabric by setting the dimension of the width of the fabric. After being processed by the squeezer, the fabric is not stable; the yarn loops formed may not be in their most stable state.

Moreover, after going through the squeezer, the fabric has a percentage humidity of 70%. The aim of the stenter is to bring down this percentage to 7%. Below this level, the fabric is said to be overdried.

The process of heat setting makes use of the highest temperature in the the stenter which may be around 150^0C or higher.

For performing the processes on the stenter, fresh air is aspired from the atmosphere, heated by making use of a radiator and then forced through nozzles which are used to heat the fabric. The radiator is heated by thermal oil through a thermal oil heater. The excess hot air is blown out of the stenter chambers and the rest is recirculated.

Taking into consideration the high temperature of the air leaving the stenter and the high volume flow rate of the air, since the drying chambers of the stenters can extend over 50m in length, large amount of waste heat can be recuperated.

Since the incoming air into the stenter needs to be heated to high temperatures, the incoming air can be preheated by the air exhaust, hence decreasing the amount of heating required through the radiators. A shell and tube counter flow heat exchanger can be used for this purpose. Fig. 3 shows a possible arrangement of the system.

The hot air blown through the heat exchanger may be expected to be lower than 150^0C based on the processes being performed on the stenter. Taking into consideration the size of the stenter and the rate at which the finishing operations are performed on the stenter, large amount of air is expected to be blown out through the heat exchanger and a similar volume of air is expected to be blown into the stenter from the atmosphere. Eventually, large amount of heat is expected to be transferred in the heat exchanger. Quantification of the energy recuperated would depend on the stenter and its operation.

It should also be noted that finishing floors also consist of dryers together with stenters. Dryers also operate at high temperatures which can increase up to 120^0C. Again, these high exhaust air temperatures can be used to pre-heat the incoming air from the atmosphere.

Alternatively, all the air exhaust from the stenters and the dryers can be used to heat water in the hot water tank.

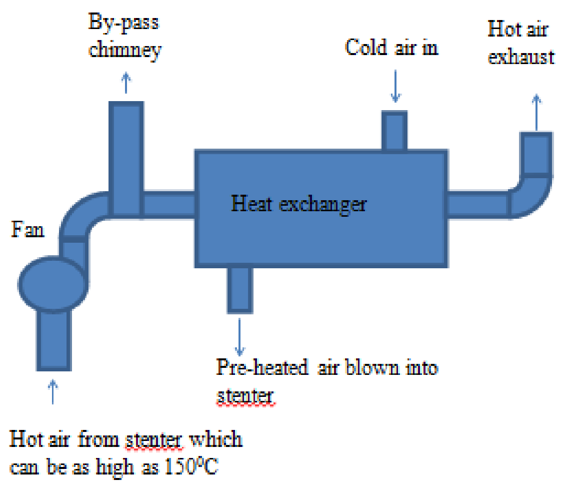

Fig. 3- Heat recovery system for the stenter

C. Other energy conservation measures

It should be noted steam and thermal oil systems are commonly used in textile mills for heating purposes. Steam is used in dyeing machines and thermal oil is used in stenters and dryers. The temperatures used are well above the temperatures to be reached by the dye bath and hot air respectively.

For the steam systems, in addition to efficient condensate recuperation, proper thermal lagging should be used in the pipe circuits. Glass fibres are commonly used for this purpose. However, cladding is another option to further decrease heat losses. The same applies for thermal oil pipelines.

Boilers are a major component of the dyehouse. An efficient boiler would lead to optimum use of energy an fuels.

For a boiler to operate at its optimum condition, the following factors must be considered:

- The fuel is burnt the most efficiently possible (combustion efficiency).
- Heat is transferred from the products of combustion of the fuel to the water in the boiler shell the most efficiently possible (heat transfer efficiency).
- Effective utilization of the steam with maximum heat recovery through the use of condensates (utilization efficiency).

Moreover, fresh water treatment is essential in textile mills for:

- Providing safe make-up feedwater for the boiler;
- Good quality dyeing in the dyehouse;
- Good performance of the heat recovery units and the boiler itself in the long term with prevention of scale and oxygen scavenging.

D. Renewable energy

Though many companies are investing in renewable energy sources such as wind power and PV cells, solar water heaters are also commonly used in many textile mills. Solar water heaters are used to preheat feedwater make-up and hot water.

Based on the location of the dyehouses, a yearly average global radiation of 5.4 kWh/m^2 can be obtained in Mauritius. Solar water heaters with evacuated tube collectors may work well, though flat plate collectors are more common in the island. Temperatures of 70^{0}C can be easily reached and, in fact, very low payback periods have been observed of 1 to 2 years.

IV. Conclusion

The dyehouse of textile mills offer many opportunities of energy management. Apart from common energy conservation measures that are adopted in many textile mills, such as lagging of pipes, other energy conservation measures have been discussed in this project. The latter measures proposed look into:

- Waste water heat recuperation;
- Thermally insulate the dyeing machines
- Use of heat exchangers to pre-heat air into the finishing machines.

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