Design of Heat Recovery System for Dye Effluent in Textile Industries

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***Abstrac*t--Heat Transfer indeed a relevant subject. We will devote much time to acquire an understanding of heat transfer effect and to develop the skills needed to predict the heat transfer rate. What is value of this knowledge? And to What kinds of problem may it be applied? Heat transfer is commonly encountered in engineering system and other aspects of life and one does not need to go very far to see some application areas of heat transfer many ordinary household appliances are designed in whole or in a part, by using this principle of heat transfer. Some example includes the heating or air conditioning system, the refrigerator, the freezer, water heater, the iron, and even the computer, the TV. Of course energy efficient homes are designed on the basis of minimizing the heat loss in winter and heat gain in summer.**

Heat transfer plays a major role in the design of many other devices such as car radiator, solar collectors, various components of power plant and even spacecraft. The thickness of insulation in the walls and roofs or the houses and water heater again determined on the basis of heat transfer analysis of with economic consideration. The first law of thermodynamic provides useful tool for many heat transfer problems. The energy generation term is associated with conversion from some other energy form (chemical, electrical, electromagnetic or nuclear) to thermal energy. It net effect is an increase in the thermal energy of matter within the control volume.

In most of the textile industries, they require hot water for dyeing process, dyeing process is a process where the cloths are being colored. They require approximately 80°C temperature for this process which is produced by the boiler in the form of steam. As dyeing process is over the hot water is drained. This hot waste water instead of being wasted and before going to drained we can retract and recover the heat from this hot waste water and give to the cold water so as raise its temperature by effectiveness of our heat recovery system.

INTRODUCTION

Heat Recovery from Water: - Re-use

The first heat recovery option to consider is the reuse of the hot waste water. In this way, water, residual chemical as well as energy are recovered. In textile dyeing and finishing operations involving acrylic fibers or wool where colorants are exhausted, waste water reuse is possible similarly waste water from rinsing operations can make up new baths ,for instants ,for scouring (Phipps1974) dyeing and finishing specialist claim that waste water from light shade operations can be re utilized up to 20 times.

Cooling of baths is a common operation .The utilization of cooling water, i.e. of stream of cold water to absorb heat from the hot bath can also be considered as a heat recovery process. Subsequently, cooling water is collected and re-utilized thus, recovering heat and water. Localized heat recovery (energy recycling) equipment such as washing, mercerizing, dyeing, and bleaching machines often operate continuously for long hours requiring a large volume of hot water and produce an equal volume of hot waste water simultaneously. A characteristic feature of some technology is the incorporation of heat exchangers on such textile machines with purpose of heating up the incoming cold water stream with hot wastewater leaving the machine.

1.1 Present theories and practices:-

Centralized waste water heat recovery batch or non-continuous processing is common in many plants. Thus, a large volume of wastewater is available intermittently from several machines at different location in the plant. If wastewater can neither be reused nor can its heat be recovered locally the feasibility of installing centralized heat recovery system should be investigated. The system should storing hot waste water in a large tank from where a hot stream is pumped to a heat exchanger in order to warm up process water. Experience has shown that payback period is invariably more than 12 months. The importance of an in-depth feasibility study should not be underestimated-examples in literature have shown that in some cases the payback period can extend over more than ten years in spite of the availability of a large volume of waste water.

Fig.1: Textile plant

1.2 Scope of the work:

Apart from the increasing use of information technology, steam utilisation is also characterised more and more by the use of gas as combustible and the decentralised of steam production and the decentralisation of steam supply needs high capital intensive investment and the payback period is generally more than 2 years. The potential to lower energy consumption by more than 20%, the reduction in process time, the absence of steam starvation and the avoidance of production bottlenecks are strong reasons for shifting to decentralised generation. Gas is practical for use in direct water heaters and directly fired dryers- it is also more environmentally friendly than coal or fuel oil or fossils fuel that are required for generation of steam.
An interesting technique under research currently involves a gas fired heater used to superheat steam generated from conventional boilers-dyeing and finishing of textile with superheated steam is reported to yield positive results in terms of quality, productivity as well as energy efficiency, although the rate of heat transfer may have to be carefully monitored. Other developments have occurred in the form of process improvements and the use of recovery techniques. The former refers to new process design, often associated with the use of information technology, to minimise not just steam consumption but also that of water and chemicals, to reduce process time and enhance quality.
The heat recovery system finds its great scope in textile industry. In India there are number of textile industries, for dying process they require hot water and consequently they use steam for heating the water which they required for dying and finishing process of cotton. After doing different process the hot water is made to flow towards the drain and this hot wastewaters temperature can be re-utilised by heat recovery system and thus we can do the energy conservation by reducing the temperature required by for heating the cold fluid.

1.3 Objectives:
To study the best way of utilising the heat from waste hot water.

1. To study the different type of heat recovery system.
2. To study the most efficient and feasible design for the heat recovery unit in Textile industry.
3. To study the best suitable area for installation of the same.
4. To design a maximum efficient unit so as to reduce the energy required for heating the water for processing.

2. LITERATURE REVIEW

Many developing countries, including African ones, in 1996 look forward to developing strong integrated textile industries to add value to already-available raw materials [6]. Dyeing and finishing activities are, however, energy-intensive. In many cases, these depend on imported fossil fuels. By turning to heat recovery, significant cost savings can be achieved improving profitability and competitiveness [9]. 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[2].
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[1]. Keywords: heat recovery, textile energy management, Mauritius, dyeing, finishing industries in developing countries has been rising production costs, particularly energy (Kasita, 2009). In many cases strict environmental standards are called for, along with a reduction of reliance on imported fossil fuels [3]. Whilst dyeing and finishing activities add value to the production chain, the fact is that they are highly energy-intensive [5]. This paper focuses on lessons where heat recovery has brought significant cost reduction in textile dyeing and finishing [8]. The focus is on steam utilization in textile mills.
The first heat recovery option to consider is the reuse of the hot wastewater. In this way, water, residual chemicals as well as energy are recovered[4]. In textile dyeing and finishing, operations involving acrylic fibers or wool where colorants are exhausted, wastewater re-use is possible. Similarly, wastewater from rinsing operations can make up new baths, for instance, for scouring (Phipps, 1974) [7]. Dyeing and finishing specialists claim that wastewater from light shade operations can be re-utilized up to 20 times [6].

3. DESIGN OF HEAT RECOVERY SYSTEM

3.1 Data Collection:-
Inlet temperature of cold water: 25°C
Outlet temp. of hot waste water:60°C
Temperature required for process of dying : 80°C
Type of boiler: Wood fired Boiler
Capacity of Boiler: 1 tph
Efficiency of boiler: 75%
Fuel required : 700 kg per day
Hot water tank capacity: 1000 liters
Number of tanks: 4

3.2 Working of Plant:-
We had visited Sagar Dyeing Industry Solapur on second week of October. There were four tanks in the plant and the each tank capacity is of 1000 liters. The plant is divided in two sections one.
1) Hot washing Section

2) Cold Washing Section

The two tanks are used in hot washing section and another two used for cold washing section. In hot washing section the two tanks requires water at temperature up to 80°c. In cold washing section the temperature of two tanks is 25°c.

In this two section the dyeing process is carried out. Dyeing is the process of adding color to textile product like fibres, yarns, and fabrics. Dying is normally done in a special solution containing dyes and particular chemical material. After dying, dye molecules have uncut chemical bond with fiber molecules. The temperature and time controlling are two key factors in dying. There are mainly two cases of dye natural and manmade. Firstly the cotton or fabrics, the raw material which is to dye is stored in plant. The cloths are checked whether it is cleaned or not. If not it is cleaned by detergent and water and removes the dust fluffs etc. After this it is fed into tank where it is dipped into it for some time. Before this the water from the tank is first heated by using steam produced from the boiler. After achieving 80°c the steam valve is closed and worker puts cotton cloth into the tank. There is mechanism that revolves the cotton in tank. Then dye is mixed in the hot water.

In first tank primer is used for dying. In second hot water tank the desired color dye is used. Usually they use both natural and artificial dye. Natural dye extracted from animals or plants. And chemical dyes like acrylic fibres and dyed with basic dyes are used. For nylon and protein fibres such as wool and silk are dyed with acid dyes and polyester yarn is dyed with a range of dye types, including vat dyes, and modern synthetic reactive and direct dyes . Dyes are applied to textile goods by dyeing from dye solution and by printing from dye pastes. Methods include direct application and yarn dyeing.

After dyeing the textile goods are moved into cold washing section. In this cold washing section textile goods are cleaned at a temperature upto 25°c. After cleaning goods there are soaked. In this textile the large amount of water is required for processing. They require daily 7 tankers of water. After dyeing process is over the water from both the hot washing section and cold washing section is drained.

Fig.2: Colours used for cottan.

Fig.2 working at textile

- **Drawback of plant:-**
- Bad aesthetics and quality of dyed fabric
- The hot water used in dying process is drained
- The cotton goods contain some fluffs

3.4 Layout of Heat Recovery System in Textile Plant:-

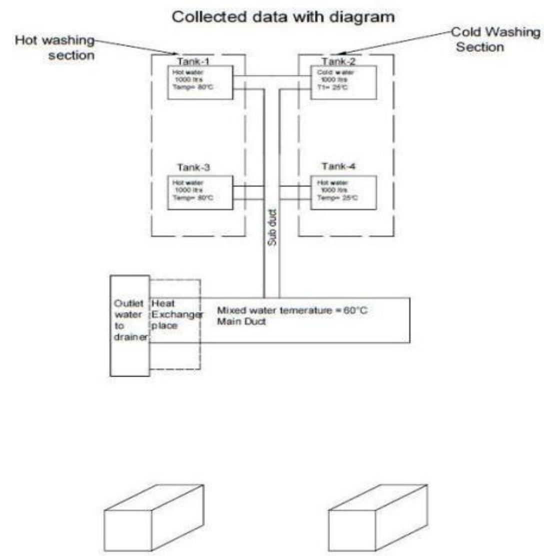

Fig.3: Heat Recovery System in Textile Plant

3.5 Improvement

The hot water which is used for dyeing process is totally wasted. The waste hot water can be used for increasing temperature of process feed water.

In this way we can recover some amount of heat by using our unit called Heat Recovery System for Dye Effluent.

Presently there is no unit for recovering the heat of hot waste water, so we have designed the new heat recovery unit which reduce fuel consumption and increases the plant efficiency.

4. PROPOSED HEAT RECOVERY UNIT

1) Schematic Diagram

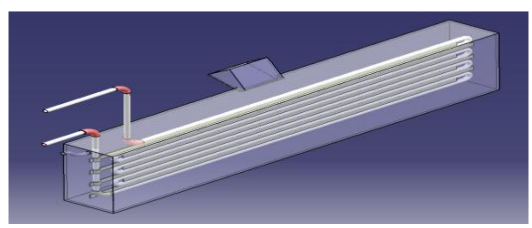

Fig. : 4 Proposed heat recovery unit

The above fig shows the conceptual diagram of heat recovery system for dye effluent. It is a rectangular shell in which the copper tubes are placed so as to recover the heat and raise the temperature of feed water. In between the tubes the mild steel plates are braced for stiffening purpose. One nozzle is provided for inlet of hot waste water. This heat recovery system is online type of heat exchanger, as water inlet and outlet are in one line so that water level in the system remains constant.

5.WHY HEAT RECOVERY SYSTEM

Nowadays textile wet processing operations are coming under increased operations are coming under increased scrutiny from environment regulators because of the complex wastewaters and air emission they generate. Wastewater temperature is form of pollution. In dying process, so much hot water is discharged that, in the absence of any counter-measures, total wastewater temperature may exceed 40°c even more. This new regulatory effort comes at a time when textile companies are already faced with the need to reduce costs to respond to increasing competition.

As textile industry, consumes energy in the form of heat. With the increasing scarcity of natural resources and spiraling costs of energy conservation today is an absolute necessity to sustain any business, for that new technology is required to recover some percentage of loss of energy. Heat Recovery System for Dye Effluent offers an opportunity for textile companies to reduce heat releases and save money and at same time, it helps you became more efficient.

We have visited Sagar Textile Industries there we have observed hot wastage water is going to drained so there we can use heat recovery system for recovering the heat. The system provides the temperature of clean water used in the dyeing plant lower than waste water. So heat recovery system via usage of the discharged energy heats cold water entering into the dyeing plant and provides you with ready hot water. You may start using the ready hot water for the following procedures.

- In bleaching process
- In dying process
- In washing processing rinsing process
- And in a steam boiler

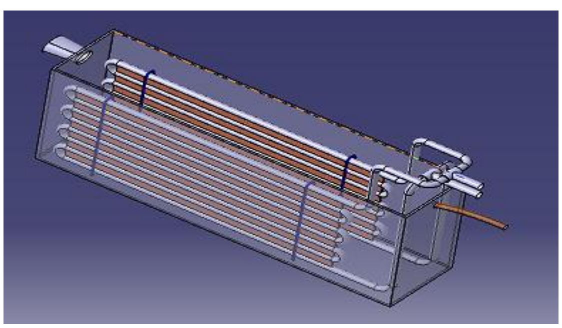

Fig. 5 CATIA MODEL

6. DESIGN STEPS

Assume tube diameter and BWG, Assume tube length, *L*

1. Assume fouling factor based on inside and outside tubes, hdi and hdo.
2. Assume material of construction for the tubes thermal conductivity.
3. Assume material of construction for the tubes thermal conductivity
4. You have the option to assume three known temperature and find the fourth one or four temperature values and find one of the shell or tube side flow rate. Use the heat duty equation Mh Cph (Th2-Th1) = Mc Cpc (Tc2-Tc1) where subscripts *c* and *h* refer to cold and hot streams. Then obtain the heat duty Q.Based on the type of flow, calculate Log Mean Temperature Difference, LMTD

5. Based on the exchanger configuration obtain the Temperature correction factor

6. Calculate the mean temperature difference using $\Theta m = Ft \times LMTD$

7. Assume overall heat transfer coefficient as initial guess from the table below:

$$F_t = \frac{\sqrt{(R^2+1)}\ln\left[\frac{(1-S)}{(1-RS)}\right]}{(R-1)\ln\left[\frac{2-S[R+1-\sqrt{(R^2+1)}]}{2-S[R+1+\sqrt{(R^2+1)}]}\right]} \qquad R=\frac{(T_1-T_2)}{(t_2-t_1)} \qquad S=\frac{(t_2-t_1)}{(T_1-t_1)}$$

8. Calculate the provisional area: -

Q= F A ΔT

9. Based on the assumed tube diameter (ID and OD at a given BWG) and tube

Length, *L*, calculate number of tubes

10 Calculate tube pitch and the bundle diameter

$$p_t = 1.25 d_o \qquad D_b = d_o\left(\frac{N_t}{K_1}\right)^{1/n_1},$$

where N_t = number of tubes,
D_b = bundle diameter, mm,
d_o = tube outside diameter, mm.

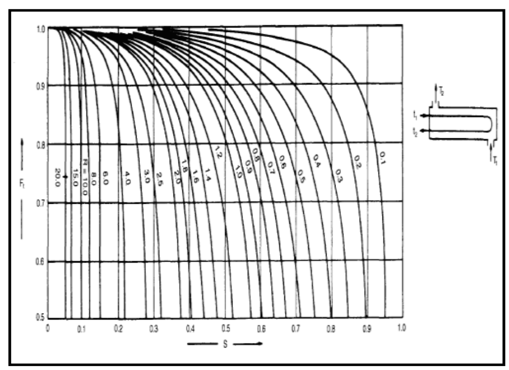

Fig.6 Temperature correction factor: one shell pass; two or more even tube 'passes

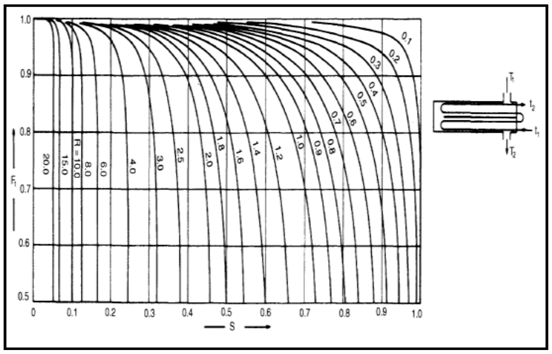

Fig.7.Temperature correction factor: two shell passes; four or multiples of four tube passes

Table.1: Typical Overall Coefficient

Hot fluid	Cold fluid	U (W/m²°C)
Shell and tube exchangers		
Heat exchangers		
Water	Water	800 - 1500
Organic solvents	Organic solvents	100 - 300
Light oils	Light oils	100 - 400
Heavy oils	Heavy oils	50 - 300
Gases	Gases	10 - 50
Coolers		
Organic solvents	Water	250 - 750
Light oils	Water	350 - 900
Heavy oils	Water	60 - 300
Gases	Water	20 - 300
Organic solvents	Brine	150 - 500
Water	Brine	600 - 1200
Gases	Brine	15 - 250
Heaters		
Steam	Water	1500 - 4000
Steam	Organic solvents	500 - 1000
Steam	Light oils	300 - 900
Steam	Heavy oils	60 - 450
Steam	Gases	30 - 300
Dowtherm	Heavy oils	50 - 300
Dowtherm	Gases	20 - 200
Flue gases	Steam	30 - 100
Flue	Hydrocarbon vapours	30 - 100
Condensers		
Aqueous vapours	Water	1000 - 1500
Organic vapours	Water	700 - 1000
Organics (some non-condensables)	Water	500 - 700
Vacuum condensers	Water	200 - 500
Vaporisers		
Steam	Aqueous solutions	1000 - 1500
Steam	Light organics	900 - 1200
Steam	Heavy organics	600 - 900
Air-cooled exchangers		
Process fluid		
Water		300 - 450
Light organics		300 - 700
Heavy organics		50 - 150
Gases, 5 - 10 bar		50 - 100
10 - 30 bar		100 - 300
Condensing hydrocarbons		300 - 600

BENEFITS

1) Percentage utilization of heat from hot waste water: 35%
2) The effectiveness of heat recovery system : 60
3) Fuel required for producing steam will be reduced
4) The operating cost and maintenance cost is less
5) Heat recovery system is compact and easy for installation
6) Rugged mechanical construction

COST ANALYSIS

<u>Cost Estimation :-</u>

Material cost + manufacturing cost = Rs. 114400 +10000
=Rs. 124400

CONCLUSION

1) Percentage utilization of heat from hot waste water: 38 %.
2) The effectiveness of heat recovery system: 60.
3) Fuel required for producing steam will be reduced
4) The operating cost and maintenance cost is less.
5) Heat recovery system is compact and easy for installation.
6) Rugged mechanical construction.

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