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NON-CONVENTIONAL TECHNOLOGIES FOR SAVING ENERGY IN TEXTILES

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Abstract: Textile sector may be considered as one of the largest industrial sector in India and at the same time it is also one of the oldest sectors in the country. Even after a lot of technological development globally, most of the mills are using the same conventional technology. Although for the last few years process of modernization in textile industries are underway but still the pace is slow. In order to accelerate the pace of energy efficiency activities in the industries, there is a need of energy conservation because power and utility plays a vital role and their cost contributes significantly on total cost of finished textile product. The energy cost is around 15 % to 20 % over the production cost and it stands next to raw material cost. In this paper unconventional techniques are mention which have opened a new era of energy conservation in textile processes.

Keywords: Unconventional techniques, ultrasound, supercritical fluid, foam technology, plasma, infrared, electrochemical.

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INTRODUCTION

The need for energy conservation has assumed paramount importance in the textile industry with the rising energy cost on the one hand and the severe energy shortage on the other. Textile mills, particularly in the South, have suffered in the last few years due to severe power shortage resulting in greater resort made to captive power through gensets, which has increased the power cost drastically. This has also contributed to generating greater awareness on finding ways to save energy costs and making the whole manufacturing process more efficient. The energy cost, next to the material cost, is around 15-20 per cent of the total production cost. Apart from the power cost, manpower shortage is yet another major problem forcing the mills to deploy more automated machines. Hence, with textile machinery manufacturers integrating automation in the machines they produce, the power requirements of mills keep rising.

As manufacturers face an increasingly competitive global business environment, they seek opportunities to reduce production costs without negatively affecting product yield or quality. Rising energy prices are driving up costs and decreasing value added at the plant. Successful, cost-effective investment into energy efficiency technologies and practices meets the challenge of product quality maintenance despite reduced production costs. This is especially important in the current age, as energy-efficient technologies often include “additional” benefits such as increasing the productivity of the company or reducing the water and/or materials consumption.

Among all the industries, textile sector consumes about 5 - 8% of the total energy mainly in the form of electrical and thermal. Out of this about 40-45% energy consumed in manufacturing of yarn and fabric and 35-60% energy utilized in wet processing [1]. Textile wet processing involved pretreatment, dyeing, printing and finishing, on grey fiber to impart aesthetic values and marketability. All the four conventional energy sources namely, coal, electricity, oil and gas are utilized in the wet processing of textile. Various approaches have been developed and practiced to conserve energy in wet processing namely, Developments of machines with low material to liquor ratio, Efficient heat recovery and processing, Developments in specialty chemicals and dyes to reduce processing time or cycles, Optimize wet pickup on fabric to reduce drying energy, Adoption of e-control to minimize unnecessary leakages, Development of techniques to reduce process cycle [1].

Innovation of unconventional techniques have opened a new era of energy conservation in textile wet processing. The important benefits to textile industry of the unconventional technologies are:

- The apparent increase in diffusion rate of chemicals.
- Energy savings as process operate at lower temperature.
- Increased efficiency of process leads to less effluent.
- Preserved drapability, luster and finish of fiber.
- Overall cost reduction of process.

Novel Concepts of Energy Conservation

Higher energy consumptions involved in textile operations make pathway to innovations in various operations involved in the chemical processing of textile materials.

Ultrasonic Assisted Wet Processing [2-4]

Ultrasonic assisted process is an alternative to conventional high temperature processing of the textile materials. Ultrasound equipment installed in the existing machines offer improved performance in fabric preparation and dyeing without impairing the properties of the processed materials. The influence of ultrasound intensifies the mass transfer in the wet processing of textile materials. The advantages of ultrasonic in textile wet processing include energy saving by reduced processing temperature, time and lower consumptions of auxiliary chemicals and further processing enhancement by control of overall costs. Therefore, the areas that demand higher energy consumption can be benefited using ultrasound techniques.

Normal audible sound frequency range for human is about 16 – 18 Hz (1 Hz = 1 Cycle for second). Ultrasound (US) is a cyclic sound pressure wave with a frequency greater than the upper limit of human hearing. US is thus not separated from "normal" (audible) sound based on differences in physical properties, only the fact that humans cannot hear it. US mainly divided into two groups, namely, power ultrasound (20 KHz – 2 MHz) and diagnostic ultrasound (5MHz – 10 MHz). The various range of sound shown in figure 1. Power US induces cavitation in liquors, mainly used in textile wet processing while diagnostic US does not induce any cavitation and used mainly in medical imaging.

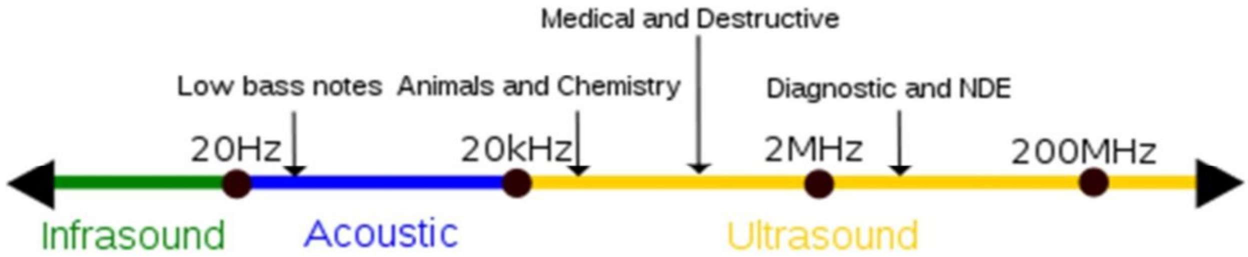


Fig: 1 US range diagram

US radiation requires medium with electric properties for propagation and with this respect, it differs from light and other form of electromagnetic waves, which travel freely in vacuum. During the propagation of ultrasonic waves, the particles in the electric medium oscillate and transfer energy through the medium in the direction of propagation. They can be propagated either longitudinally or transverse. In gas and liquid medium only longitudinal waves are transferred while in solid medium both longitudinal and transverse waves can be transmitted. The longitudinal vibration in liquid produces the phenomenon of cavitations. This cavitation's, is the form of microscopically small bubbles, which during process, expand and collapse violently and generating shock wave. The cavitation formation depends on many factors, namely, frequency and intensity of waves, temperature and vapor pressure of liquid. The important phenomenon in textile wet processing, with respect to ultrasonic waves is micro steaming i.e. large amount of vibration energy accommodated in relatively small volumes with little heating. The combine effects of cavitations and micro steaming lead to inter molecular tearing and surface rubbing. This reaction behaves as catalyst for the actual process i.e. increases the rate of processing.

The important significance of US in textile processing can be summarized as:

- Improved quality products obtained mainly in paste preparation process.
- Better dye penetration, improved uniformity and fastness properties of dyeing.
- Energy saving as the process is possible at low temperature compared to conventional process.
- Consistent and uniform bonding in the finishing process.

Supercritical Dyeing Technique [5-6]

Supercritical dyeing technique is an innovation to conserve the thermal energy as the fabric is in the dried state because at the end of process CO2 is released in gaseous state. This is a new technique of using supercritical carbon dioxide as a dyeing medium. Dyeings are performed in a high pressure vessel called an autoclave. Carbon dioxide exists as a supercritical fluid at temperature at about 31°C and pressures above 72 bar. The anhydrous process offers number of ecological and economical advantages such as, no preparation of processing water and low energy consumption for heating up liquor.

Supercritical fluid (SCF) is defined as subtract above its critical pressure and its critical parameters could change. The study of SCF began in the 19th century, but it was only in the 20th century when the advantages of SCF for chemical processes began to realized. SCF has unique properties that may enhance many types of chemical process operations. An additional advantage of using SCF is that it solve effluent problem to large extent. Super critical carbon dioxide is by far the most widely used SCF, is relatively cheap, non-toxic, and nonflammable and has zero ozone depletion potential.

In the textile wet processing, SCF is mainly tried for the dyeing of hydrophobic fibers which in conventional process required very high temperature (≈130-140oC). Application of the said techniques for wool, cotton and polyamide fibers, creating problems because of the polar nature of dyestuffs used for them. Supercritical dyeing (SCD) involved only three components, namely, dyestuff powder, subtract and SCF (mainly carbon dioxide). In the actual process dyestuff powder dissolved in SCF, transferred to fiber surface and finally diffused in the fiber structure (figure – 2).

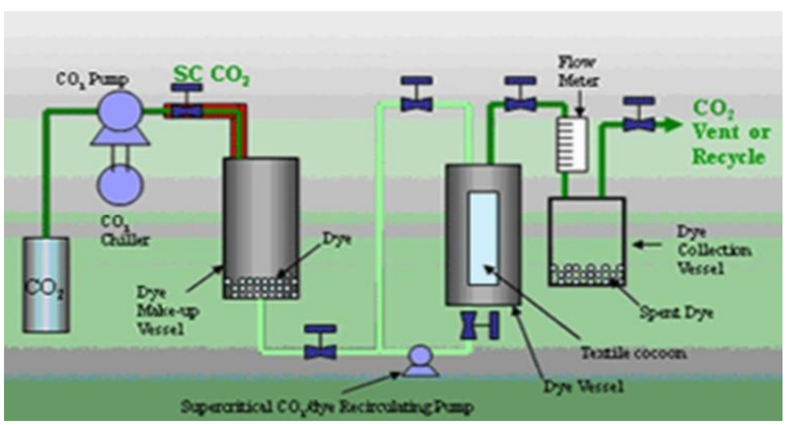


Fig: 2 CO_2 dyeing of PET

The important advantages of SCF – CO2 can be summarized as

- Eliminates water and effluent problems.
- No need of drying after dyeing process.
- Excellent dyeing results in terms of evenness and fastness properties.
- SCF can be recycled and used in subsequent process.
- Reduction in energy consumption (about 40-50 %) and air pollution

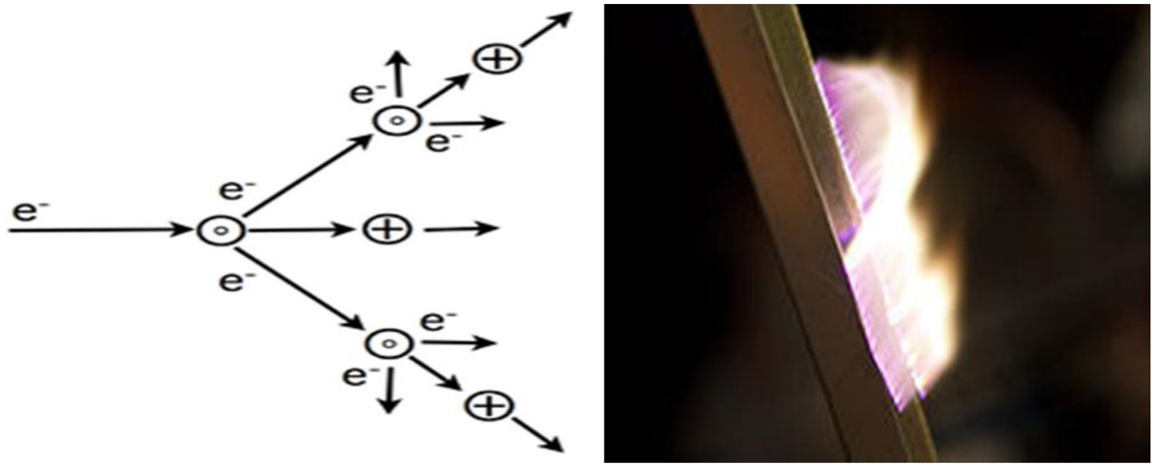
Despite outstanding successes in this area and great potential, there is a lack of understanding of the importance of dyestuffs solubility in supercritical carbon dioxide to dyeing processes. In addition, there has been little study on the kinetics of dyeing process or supercritical carbon dioxide flow characteristics in porous (textile) materials.

Foam Technology [2]

The application of foam processing leads to considerable savings in the energy required for heating, drying, thermo-fixing, and steaming and so on because the water content is very low. The foam processes bring down the liquor ratios required for pretreatment, dyeing and finishing by producing uniform foam with the required characteristics in terms of viscosity, stability, and blow ratio. De-sizing, bleaching and finishing as well as fluorescent brightening of goods can be done using a foam technique. It offers potential savings in materials and energy.

Plasma Treatment [7-10]

Plasma is an ionized gas with equal density of positive and negative charges which exist over an extremely wide range of temperature and pressure. Plasma consists of free electrons, ions, radicals UV-radiation and other particles depending upon the gas used. In order to maintain a steady state, it is necessary to apply an electric field to the gas plasma, which is generated in a chamber at low pressure. Plasma is the 4th state of matter and a gas becomes plasma when the kinetic energy of the gas particles rises to equal the ionisation energy of the gas. When this level is reached, collisions of the gas particles cause a rapid cascading ionisation, resulting in plasma (figure – 4a).



(a) (b)

Fig:4 (a) Cascade process of ionization. Electrons are 'e–', neutral atoms 'o', and cations '+', (b) Artificial plasma produced in air.

The conventional wet treatment used in textile mainly concern with energy, cost and environmental issues. Application of plasma at low temperature in textile processing can prove to be the best alternative for these issues. Unlike conventional wet processes, which penetrate deeply into fibers, plasma only reacts with the fabric surface (nanometer range) that will not affect the internal structure of the fiber. Further, plasma technology modify the chemical structure as well as the surface properties of textile materials, deposit chemical materials (plasma polymerization) to add up functionality, or remove substances (plasma etching) from the textile materials for better applicability. In textile processing, this technology can be explored in various areas like pretreatment, dyeing and finishing through different methodology vis-à-vis glow, corona and dielectric barrier discharge methods to add functionality and modification of surface properties of textile materials. Plasma technology is a surface-sensitive method that allows selective modification in the nm-range. Different reactive species in the plasma chamber (a mixture of electrons, ionised atoms and molecules, photons and residual neutral species) interact with the substrate surface. Depending on the parameters used, different treatments like cleaning, modification or coating occur.

Table 1. Various application of plasma in textile finishing

Application	Material	Treatment
Hydrophilic finish	PP, PET, PE	Oxygen plasma

Hydrophobic finish	Cotton, P-C blend	AiSiloxane plasma
Antistatic finish	Rayon, PET	Plasma consisting of dimethylsilane
Reduced felting	Wool	Oxygen plasma
Crease resistance	Wool, cotton	Nitrogen plasma
Improved capillarity	Wool, cotton	Oxygen plasma
UV protection	Cotton/PET	HMDSO plasma
Flame retardancy	PAN, Cotton, Rayon	Plasma containing phosphorus

The important significance of plasma technology in textile wet processing can be summarized as:

- It is applicable to most of textile materials for surface treatment.
- Optimization of surface properties of textile materials without any alternation of the inherent proper ties of the textile materials.
- It is dry textile treatment processing without any expenses on effluent treatment.
- It is a green process without generation of chemicals, solvents or harmful substances.
- The consumption of chemicals is very low due to the physical process.
- It is applied for different kinds of textile treatment to generate more novel products to satisfy customer's need and requirement.
- It is simple process which could be easily automated and perfect parameter control.

5. Application of infrared in textile wet processing [11-13]

Infrared (IR) is radiant energy, more accurately, it is electromagnetic radiation. IR is energy emitted by any object, which has a temperature above absolute zero (i.e. 0K or -2730C) (figure – 5a). IR is produced as continuous band of wavelength in the range of 0.8 microns to 1 mm. As temperature is increased, the intensity of IR radiation increases considerably. For effective heating of the products with IR it is important that the temperature of the IR emitter is significantly higher than that of the product, so that there is not energy flow to the product. IR for process of heating divided into three bands, namely, short (< 2 microns), medium (between 2 and 4 microns) and long (> 4 microns). In case of textile material drying process, a combined system, namely, IR and convection or air provides the removal of evaporated water (figure 5b).

(a) **(b)**

Fig:5 (a) Principle of IR generation, (b) IR dryer.

The important advantages of IR techniques in comparison to conventional curing and drying are:

- Distributes even heat throughout the material
- Provide well controlled and low intensity heat
- Intensity of heat can be varied quickly as per the products
- Lower energy cost and less space required

Application of electrochemical technique [14-15].

Traditionally, electrochemical (EC) techniques have been used for the synthesis of compound or metal recovery treatment. But more recently, a wide range of other applications have been proposed. Some of them are developed to solve several technical problems of textile industry. One of the interesting use of EC technique is in the bleaching of cotton fibers and the bleaching of finished denim fabrics. In order to achieve the visual effect in jeans, the generation of in situ of hypochlorite by EC reaction has been proposed instead of its addition. Their application in sulphur and vat color dyeing processes is also interesting. In this case, dyes are reduced by means of EC reaction (instead of sodium dithionite). In this way process becomes cleaner as no addition of chemical reagents.

Although EC methods play an important role in different textile processes listed above, their wider range of applications are related to color removal in waste water treatment, in particular, in the degradation of non-biodegradable dyes. In general, EC methods are cleaner than physicochemical and membranes technologies because the use the electron as unique reagent and they do not produce solid sludge.

EC techniques also used to produce smart textiles by obtaining functionalized fabrics. These textiles, with specific properties can be obtained using EC in the synthesis of conductive polymers, especially conductive fibers. In this category they used, to obtain a stable conducting materials as product, grafting or inserting organic compounds to modify based fiber and super critical treatment of textile through complex reaction between a metal and chemical structure of fiber.

Renewable sources of energy [02]

The different alternative renewable sources of energy are biomass, geothermal energy, tidal energy, wind energy and solar energy. Out of these energy sources, solar energy is abundant and is inexhaustible, in fact, fossil fuel, viz. coal, oil and natural gas are their origin to these energy sources. India's geographical location favours unlimited and uninterrupted supply of solar energy and hence it must be effectively utilized. Solar energy is widely utilized in the heating up of water. Solar water heaters are available that are used to save thermal energy to a great extent. The bagasse and biogas is used as fuel in the boilers which is readily available. The gas can be produced and consumed at the place of production and hence cost of transportation of raw material and gaseous product is eliminated. The technology is simple and easy to operate, with virtually very little maintenance cost. There will not be any problem of air pollution. In short, nothing is wasted and there is no effluent.

CONCLUSION

By using this unconventional techniques like Ultrasonic dyeing we can increased exhaustion & fixation by 20-25%, energy saving by 40%, reduced dyeing time by 30%, & save water by 20% than conventional dyeing. By using Plasma we can save energy and time because of low temp. Applications & elimination of drying process. By using Supercritical fluid energy required is about 40-80% less compared to conventional dyeing, dyeing time also be reduced up to 25-50%. And by using Infrared dryer we get lower energy cost and less space is required for drying.

Modernization through plant and machinery could be effective in reducing energy consumption. Some of the important factors for energy conservation are energy audit, maintenance, instrumental control, waste heat recovery, etc. Much research has been carried out for the use of unconventional techniques. However, due to high capital cost, these have not been found wide application in textile industry.

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