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Textiles Material Dyeing with Supercritical Carbon Dioxide (CO_2) without using Water

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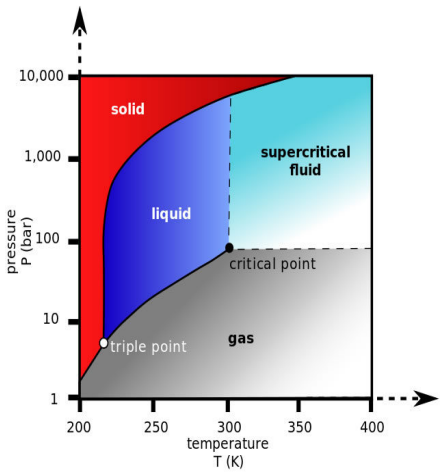
Abstract:
Water is known as much valuable resource for existing in the entire world for its multifunctional properties. So, Scarcity of water and increased environmental awareness are world-wide concerns and that causes a sharp rise in prices for drinking and removal of water. It is well known that the textile industry is one of the largest consumers of water. Conventional textile dyeing uses huge amounts of fresh water and which then is disposed as waste water containing dyestuff chemicals. Water is used as a solvent in many pre-treatment and finishing processes in the textile industry, such as washing, scouring, bleaching dyeing and finishing. So the experts are tried to develop a new technology to dye the textile material without using water (waterless dyeing technology). Elimination of the water process and chemicals will be a real and significant advance for the textile dyeing industry. This new process utilizes by-product carbon dioxide (CO_2) for dyeing textile-materials. It is a completely waterless dyeing process using recycled carbon dioxide in certain temperature and pressure.
Key words: Waterless dyeing process, Save the environment from polluted water, Reduction the consumption of water, Rapid process.

Introduction:

It is noticed that the textile industry is one of the biggest consumer of water. Every day the industry is using huge number of water for coloration the textile material. Coloration involved

- Pretreatment,
- Dyeing process and
- After treatment (Finishing).

On average an estimated 100- 145 liter of water is needed to process 1(one) kg of textile material. Water is used as a solvent in many pretreatment and finishing processes as well as coloration process, such as washing, scouring, bleaching, dyeing and to impart some special finishing effects into the textile material. Although there have been efforts to reduce the water input such as altering conventional equipment, recycling water and reusing wastewater—water usage is still high in the textile industry. So, for solving this problem the experts are trying to invention a new technology. The experts tried to find out a chemical that is capable to be liquid as well as gas in certain environment (certain temperature and pressure). Final the dream come true, a new technology has been introduced to dye the textile material without water called Supercritical Fluid Dyeing Technology. For this CO_2 is used, that has capacity to be liquid and gas state in certain pressure and temperature.



It is found that when carbon dioxide is heated to above 310°K and pressurized to above 74 bar, it becomes supercritical, a state of matter that can be seen as an expanded liquid, or a heavily compressed gas. In short, above the critical point, carbon dioxide has properties of both a liquid and a gas. In this way supercritical CO_2, has liquid-like densities, which is advantageous for dissolving hydrophobic dyes, and gas-like low viscosities and diffusion properties, which can lead to shorter dyeing times compared to water. Compared to water dyeing, the extraction of carbon dioxide dyeing process which involves only changing the temperature and pressure conditions; drying is not required because at the end of the process CO_2 is released in the gaseous state.

Dyeing process:

Supercritical fluid refers to the phase of a substance with both temperature and pressure higher than the critical point (the point where liquid and gaseous phases of a substance become impossible to tell apart). This phase of a substance enjoys many advantages and can replace water in the dyeing process. The supercritical fluid normally used is carbon dioxide (CO_2), as the critical temperature and pressure are easier to achieve than that of other substances. Moreover, carbon dioxide is also non-flammable without residues, so it is suitable for industrial use.

The dyeing takes place in following steps

- Dye should soluble in super critical fluid of CO_2
- Penetrate to the fibers (sorption)
- Adsorption of dye on fiber surface and
- Diffusion of dye molecules into the fiber molecules

To dye the textile material first of all the material is to be wrapped around a perforated stainless steel tube. After this it should be mounted inside the autoclave around the agitator. Dyestuff powder is placed at the bottom of the vessel and the apparatus is preserved, cleaned with gaseous CO_2 and preheated. When it reaches the working temperature 310^0K, CO_2 is isothermally compressed to the chosen working pressure under constant stirring. Pressure above 74 bar is maintained for a dyeing period of 50 to 70 minutes and there for bath will be dropped. Afterwards the CO_2 and excess dyes are separated and recycled.
After this dyeing procedure, the residual dyes (unfixed dyes) are removed by rinsing with acetone if necessary.

The table below compares conventional dyeing to dyeing with supercritical CO_2

CONVENTIONAL DYEING	DYEING IN SUPERCRITICAL CO_2
Huge amount of water is required for wet processing technology of textile material during processing.	No water is required for wet processing technology of textile material during processing.
High volumes of waste water with the residual dye chemicals.	No waste water at all. Dye remains as powder.
High-energy requirements.	Only 20% energy requirement
Dyeing/washing, drying times is 3-4 hrs	Only 15- 60 minutes are required for dyeing/washing

Advantages:

- Water is not needed during coloration.
- Drying is not required due to gaseous characteristics of carbon dioxide (CO_2).
- Save the environment by eliminating water pollution.
- There no risk of explosion of boiler and machine as the probability to use hard water.
- No probability to create stain on the surface of fabric of various salts of calcium (Ca) and magnesium (Mg).
- Dyeing occurs with high degree of levelness.
- CO_2 easily recyclable in dying process as it is obtained from natural resources.
- CO_2 is non toxic.
- Short time required.

Disadvantages:

- CO_2 should take into the super critical fluid state by maintaining the proper temperature and pressure.
- High pressure and temperature is needed.
- Highly skilled manpower is needed
- Investment cost high
- Complex dyeing process

Objectives of the study:
The aims of this research project are to develop the dyeing process by using a technology that will be environmental friendly, easy as well as cheap. As we know vast amount if water are to use for coloration including pretreatment, dyeing and after treatment process and the water become waste. So, to reduce the use of this scare resource (water) and to save the environment from polluted water a technology should be developed. The authors tried to find out the technology by which textile material can be dyed without water.

Methodology:
Waterless dyeing process by using supercritical CO_2 is under research. This research based on secondary data.

Conclusion:
Dyeing with super critical CO_2 is still at its early life. It has been proved time and again that it's successful at laboratory scale. Large amount of research input is needed for system integration. Dyeing with this system has been found successful with synthetic as well as natural fibers. With evolution of time Supercritical CO_2 dyeing would be popular one day by concerning save environment (free from polluted water).

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