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WATERLESS PROCESSING OF TEXTILES USING SUPERCRITICAL CARBON DIOXIDE TECHNOLOGY

THE SYNTHETIC AND ART SILK MILLS' RESEARCH ASSOCIATION

MUMBAI

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OUTLINE OF PRESENTATION / DISCUSSION

- CHALLENGES FACED BY TEXTILE WET PROCESSORS
- CURRENT PRACTICES
- SUPER CRITICAL CARBON DIOXIDE IN TEXTILE DYEING
- SASMIRA'S APPROACH
- SALIENT BENEFITS
- COST ECONOMICS ON DEVELOPED PROTOTYPE
- WAY FORWARD

CHALLENGES FACED.....

The current scenario

WATER

Raw material

Energy

Wet Processing

Processed products

WASTE

Problems associated with wet processing Industry

- Textile wet processing industry consumes huge amount of water and chemicals for its various activities
- The waste water drained after the wet processing contributes to water body pollution
- These effluent released in rivulets generates high pollution in water and is dangerous for human as well as marine life
- Textile effluents have to be treated to limits as stipulated by pollution norms
- Different methods and aspects of textile effluents and its management to save the environment from polluting are being practiced
- However, huge initial capital cost are involved in most of these treatment techniques
- The industry now needs environmentally friendly processing methods

CURRENT PRACTICES

Different methods for effluent treatment

- **Preliminary:** Removal of large solids such as rags, sticks, grit and grease that may result in damage to equipment or operational problems (Physical);
- **Primary:** Removal of floating and settelable materials, i.e. suspended solids and organic matter (Physical and Chemical);
- **Secondary:** Removal of biodegradable organic matter and suspended solids (Biological and Chemical);
- **Tertiary:** Removal of residual suspended solids / dissolved solids (Physical, Chemical and Biological)
- **Additionally Membrane filtration** and Multiple Effect Evaporator systems have been adopted for water recovery, reuse and to achieve Zero Liquid Discharge.

The alternatives so far

- Low liquor ratio processes/machines
- Combined processes
- Reuse/recycle of water
- Zero Liquid Discharge (ZLD) – effluent management

CURATIVE MEASURES
Extra measures required for effluent treatment

SC-CO_2 Technology (waterless technology)

PREVENTIVE MEASURE

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SUPERCRITICAL CARBON DIOXIDE IN TEXTILE DYEING

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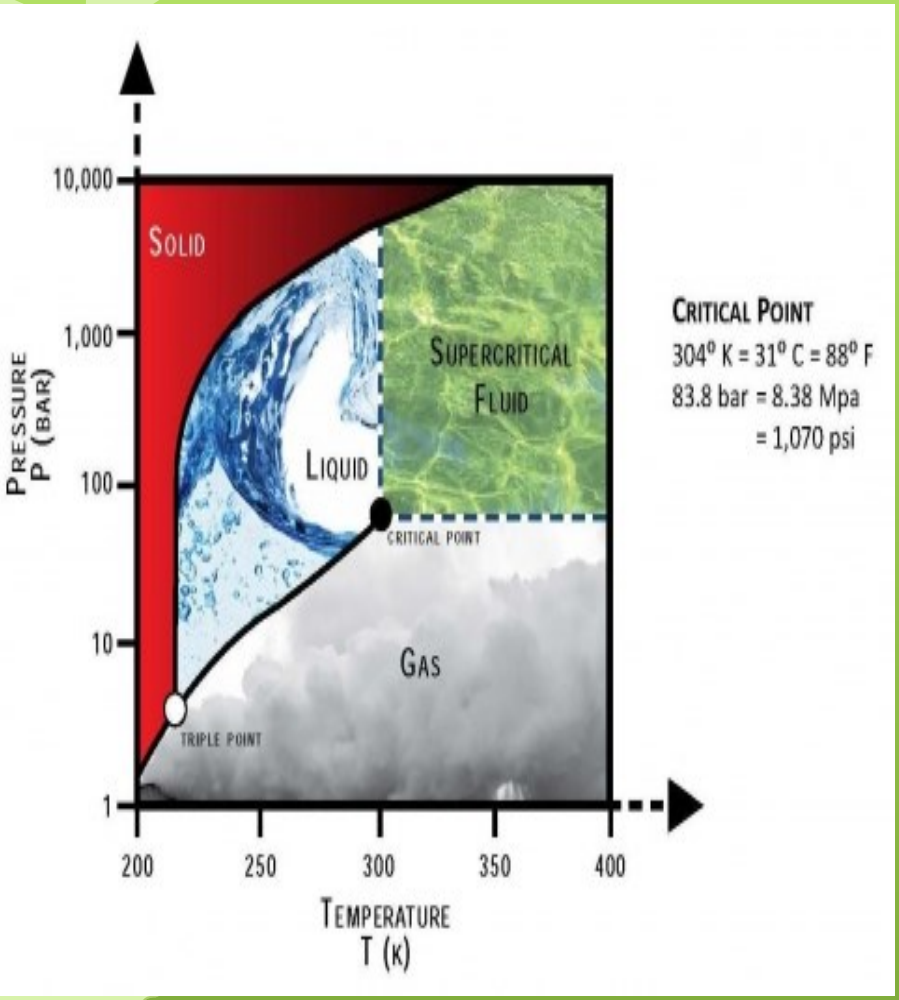
Table 1.1 *Comparison of textile dyeing processes*

Conventional water textile dyeing	Alternative textile dyeing with $scCO_2$
· Large usage of water	· Elimination of water usage
· High levels of salt and alkali	· No additives
· Hydrolysis of dye molecules	· No hydrolysis of dye molecules
· Costly water purification	· No production of polluted water
· Drying step of textile	· No drying step (energy saving)
	· Shorter process time due to high diffusion coefficients and low mass transfer resistance
	· Easy separation of the dye from $scCO_2$ with dye recovery
	· Carbon dioxide can be reused

Conducive Solution

- Environmental problems have caused reorientation of thinking and promoted research for replacement of conventional technologies
- Cleaner production is an attractive approach to tackle environmental problems
- **Application of Supercritical Carbon Dioxide in textile dyeing can provide solace to the textile wet processors**

What is Supercritical Carbon Dioxide?



- Supercritical carbon dioxide is a fluid state of carbon dioxide where it is held at or above its critical temperature and critical pressure.

- It has the unique ability to diffuse through solids like a gas, and dissolve materials like a liquid.

- Supercritical carbon dioxide is well established as a solvent for use in extraction of natural products, essential oils, pharmaceuticals, etc.

Why Supercritical Carbon Dioxide?

- Carbon dioxide is inexpensive, non-toxic, non-flammable, environmentally friendly, chemically inert and has got low critical temperature compared to other fluids

- The special combination of gas-like diffusivity and liquid like-density of supercritical carbon dioxide results to being an excellent solvent

- The density of supercritical carbon dioxide can be tuned easily by small changes in pressure

- From an environmental and safety point of view, supercritical carbon dioxide will be the best solvent to replace water in textile dyeing

Supercritical Carbon Dioxide (SC-CO_2) in Textile dyeing

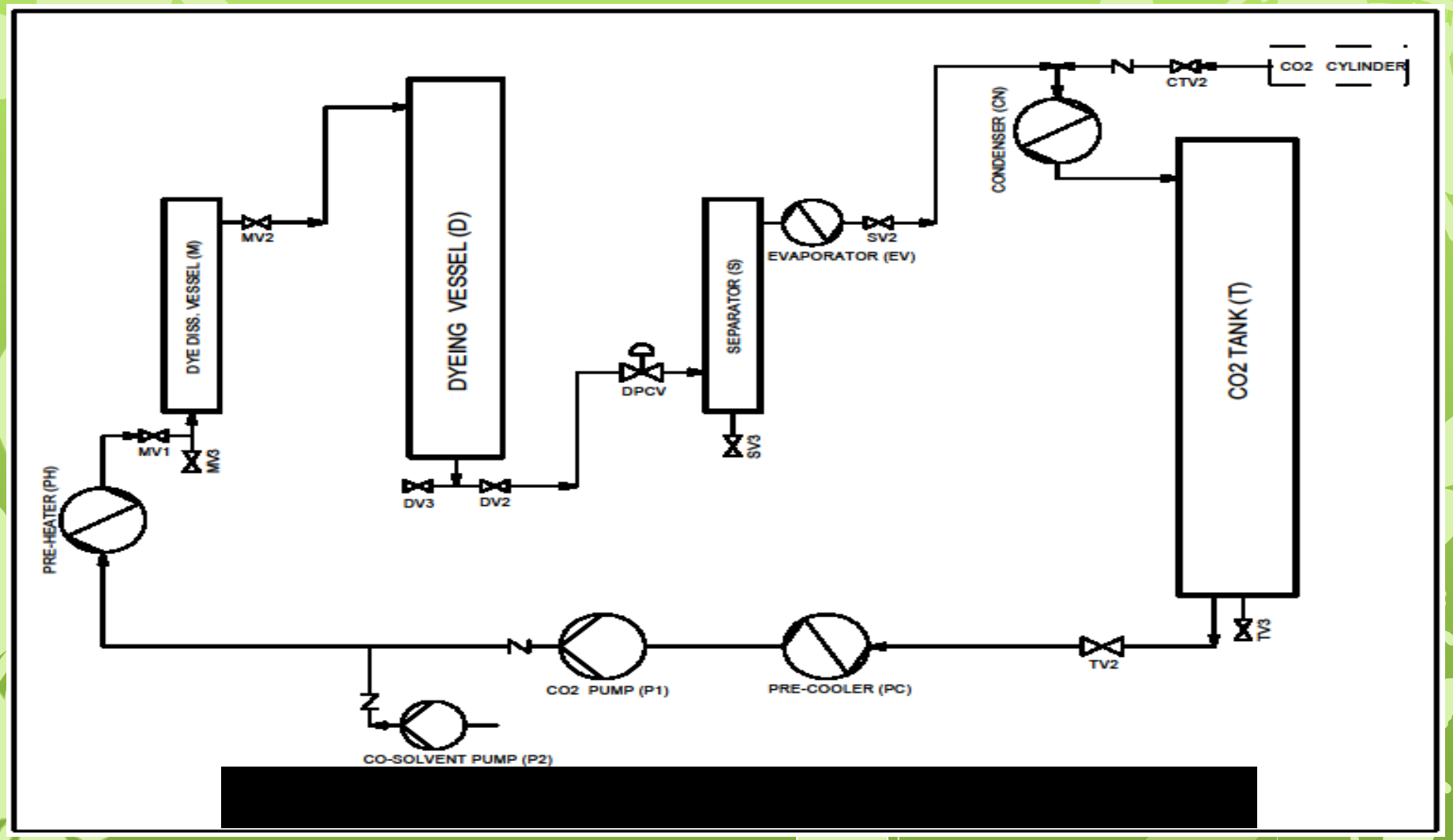
- The dyeing takes place in following steps:
  - Dissolution of dye in SC-CO_2
  - Transport of dissolved dye in SC-CO_2 to the fibres
  - Adsorption of dye on fiber surface
  - Diffusion of dye into the fibre

SASMIRA'S APPROACH

Development of vessel for supercritical carbon dioxide (SC-CO2) dyeing of textile fibers

- SASMIRA, under the Ministry of Textiles, Govt. of India sponsored project, has designed and developed a prototype model of supercritical carbon dioxide for textile dyeing
- The developed prototype is a distinct set-up exclusively for carrying out the dyeing process using SC-CO_2 technology
- In this set-up, the supercritical carbon dioxide dissolves and carries the dye onto the fibre/fabric thus facilitating water-free dyeing
- Extensive trials conducted for standardizing the process parameters and fastness properties of polyester with disperse dyes
- Comparison with conventional dyeing for process standardization
- A Patent has been applied on the developed prototype

Flow Chart of SC-CO_2 Set-up



Subsystems of SC-CO_2 Set-up

The subsystems are:

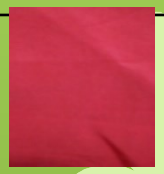
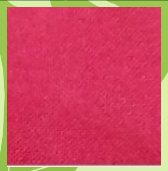
- CO_2 gas cylinder
- Condenser
- Brine Chiller system
- High Pressure Carbon dioxide pump
- Heat exchanger
- Dye solublization vessel
- Dyeing vessel
- Separator
- CO_2 flow meter
- Control Panel

PROTOTYPE MODEL

1. CO_2 gas reservoir 2. Condenser 3. Chiller 4. High pressure pump 5. Dye solubilsation vessel 6. Dyeing vessel 7. Separator 8 .Control panel (PLC)

INNOVATION / FINDINGS

Comparison of SC-CO2 dyeing vis-a-vis conventional dyeing

S. N	Dyes	Substrate	Parameters					SC-CO_2 Sample	Conv sample
			K/s (SC-CO_2)	K/s (conv)	Rubbing fastness	Light fastness	Washing fastness		
1	C. I. Disperse Red 60	Polyester Fibre	11.02	10.56	4-5	4-5	4-5		
2	C. I. Disperse Red 60	Polyester Fabric	2.91	2.87	4-5	4-5	4-5		
3	C. I. Disperse Blue 73	Polyester Fabric	8.30	8.05	4-5	4-5	4-5		

Salient features of developed SC-CO_2 set-up for textile dyeing

- Water free dyeing
- No waste water discharge hence no effluents
- Elimination of drying process
- Recycling of the carbon dioxide
- Green and clean process
- Collection of unused dye
- Exhaustion and fixation at par with conventional dyeing method

Accolades

- Indian Patent: 2896/MUM/2015
- SILVER AWARD at the 46th SKOCH AWARDS 2016
- First prize at TIT&S, Bhiwani , GCRSTS 2016
- National publications

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COST ECONOMICS FOR DEVELOPED PROTOTYPE

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COSTING FOR CONDUCTING TRIAL ON THE SC-CO2 SET-UP FOR TEXTILE DYEING (20 LITRES)

Cost of carbondioxide Rs. 2100 (1750 recovered)
(Rs. 1250 per cylinder refilling of 30 Kg)
Rs. 2100/- (required quantity 50 Kg for 5 hours)

Electricity consumption Rs. 480
(8 kW consumption load per hour)
Batch hour is 5 hours
Rs. 480/- (@Rs.12/unit)

Dye Cost Rs. 150
(300 gms of dyes @ 2% shade for 15 kg fabric loaded**)**
(@500/Kg)

TOTAL **Rs. 2,730**
≈ Rs. 3000 for 15 Kg fabric (70 gsm) = 250 metres of fabric
≈ Rs. 200 per Kg of fabric
≈ Rs. 12 per metre **[Rs. 2730 – 1750 ≈ Rs. 980 (actual 3.92/meter]**
≈ 90% recovery of CO_2
≈No effluent treatment cost

Conventional dyeing cost for Polyester is Rs 6-12/Mtr

WAY FORWARD…..

PROPOSED SC-CO_2 SET-UP FOR TEXTILE PROCESSING OF 100 LITRES CAPACITY

Sub Components:

- CO_2 gas cylinder
- Condenser
- Brine Chiller system
- High Pressure Carbon dioxide pump
- Heat exchanger
- Dye solublization vessel
- Dyeing vessel
- Separator
- CO_2 flow meter
- CO_2 storage tank
- PLC – SCADA CONTROL SYSTEM WITH HMI & CONTROL PANEL

Dimension:

Dimension of dyeing autoclave:

Inner diameter: 300 mm

Inner length: 1470 mm

Maximum working conditions:

Dyeing temperature maximum: 150 ^{0}C

Pressure Maximum: 350 bar

Orientation: Horizontal

Acknowledgement

- The Organizers of Textiles India 2017 for their support and assistance

- Ministry of Textile for approving and funding the Project on Development of the SC-CO2 set-up for textile dyeing

- The Industry partners of the project

- Management of SASMIRA

Thank You