MODULE 4 DYEING MECHANISMS

UNIT 1 TEXTILE DYEING PROCESS

CONTENTS

1.0 INTRODUCTION

In every sphere of industrial activity colour is needed. Dyeing machine is the device that is used by different industries for imparting colours. From paper to plastic to textiles everywhere there is use of Dyeing Machinery. According to the need of each type of substrate, different set of machines are put to use. The applications of this machinery give an impetus to the products related to dyeing. However, rising energy prices is having a knock-on effect on manufacturing expenditure for dyeing machinery. Therefore, there will be greater interest globally in machinery that have a lower energy consumption along with heat recovery systems that are able to preheat the incoming cold feed water.

2.0 OBJECTIVES

By the end of the unit, you shouldbe able to state the:

- types of dyeing machine
- mechanism and operation of the batch dyeing process
- type and mechanism of continuous dye process.

3.0 HOW TO STUDY THIS UNIT

1. You are expected to read carefully, through this unit at least twice before attempting to answer the self-assessment questions or the tutor marked assignments.
2. Do not look at the solution given at the end of the unit until you are satisfied that you have done your best to get all the answers.
3. Share your difficulties with your course mates, facilitators and by consulting other relevant materials particularly the internet.
4. Note that if you follow the instructions you will feel self fulfilled that you have achieved the aim of studying this unit. This should stimulate you to do better.

4.0 MAIN CONTENT

4.1 Types of Dyeing Process

There are different types of dyeing machine depending on convenience and choice of materials to be dyed. Today computers are used to control and monitor all aspects of dyeing. Over the last twenty to thirty years, developments in dye chemistry have enabled the man-made fibre to be dyed with better fastness to light and washing, and in an ever increasing range of colours.

4.2 Batch Dyeing Process

Batch Dyeing Process is the most popular and common method used for dyeing of textile materials. Batch dyeing is also sometimes referred to as *Exhaust dyeing*. This is because in this process, the dye gets slowly transferred from a comparatively large volume dye bath to the substrate or material that is to be dyed. The time taken is also longer.

The dye is meant to 'exhaust' from dye bath to the substrate. In batch processes, textile substrates can be easily dyed at any stage of their

assembly into the desired textile product. This includes fiber, yarn, fabric or garment. Some type of batch dyeing machines can function at temperatures only up to 1000^{o}C. For example cotton, rayon, nylon, wool etc. can be dyed at 1000^{o}C or lower temperatures, while polyester and some other synthetic fibers are dyed at 1000^{o}C or even higher temperatures. There are three general types of batch dyeing machines. The first, is the one where there is circulation of fabric. Second, is the one where the dye bath gets circulated while the material that is being dyed remains stationary, and finally the third, where both the bath and material to be dyed gets circulated. Examples of dyeing machines that utilises batch dyeing process are Beck, Jet, Jigs, Beam Package dyeing machines etc.

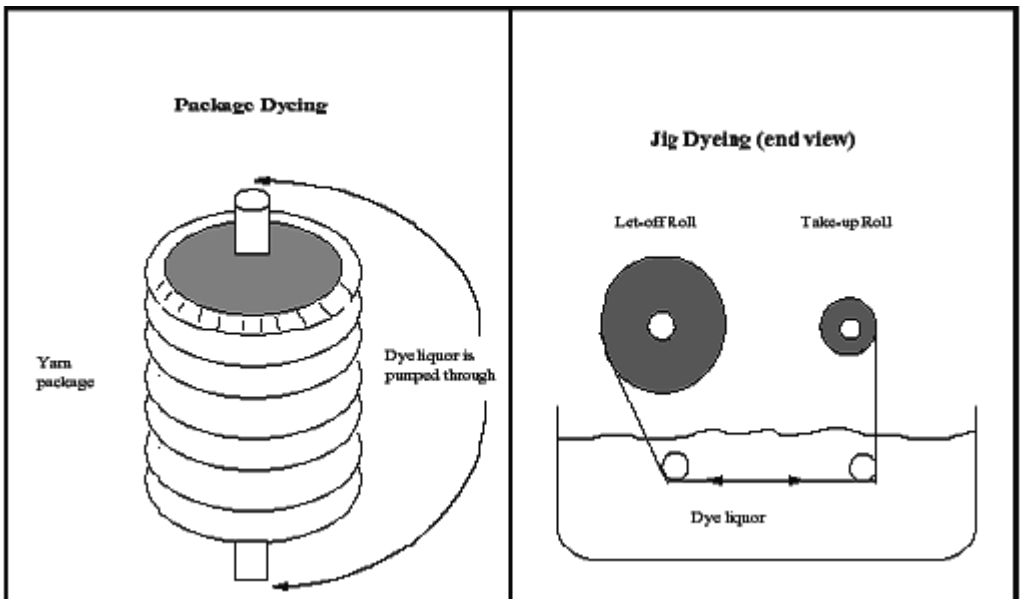


Fig. 1.1: Image Showing Popular Machines Utilising the Batch Dyeing Method

Source: www.dyespigments.com.

4.3 Continuous Dyeing Process

The working of a continuous dyeing process is described here. The textile substrates are fed continuously into a dye range. The speed can vary between 50 to 250 metres per minute. According to Industry estimates continuous dyeing is a popular dyeing method and accounts for around 60% of total average yardage of the products that are dyed.

A continuous dyeing process typically consists of the following. Dye application, dye fixation with heat or chemicals and finally washing. Continuous Dyeing has been found to be most suitable for woven fabrics. Mostly continuous dyeing is designed for blends of polyester

and cotton. The step of padding plays a key role in the operation of continuous dyeing. Sometimes nylon carpets are also dyed in continuous processes, but the design ranges for them is unlike that for flat fabrics. Warps are also dyed in continuous process. Very good examples of such warp dyeing are long chain warp dyeing and slather dyeing using indigo.

A continuous dye range has been found useful and economically sustainable for dyeing long runs of a given shade. One important factor that separates continuous dyeing from batch dyeing is the tolerance factor for colour variation. That is more for continuous dyeing as compared to batch dyeing. This is so because of two reasons (a) the speed of the process; (b) presence of a large number of process variables which affects dye application. The process that is illustrated below is designed for dyeing of blended fabric of polyester and cotton.

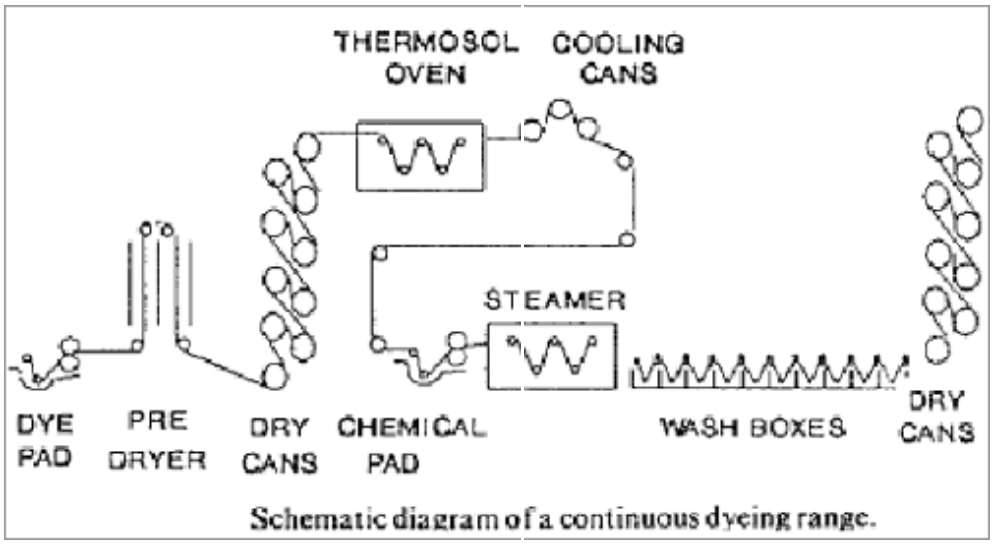


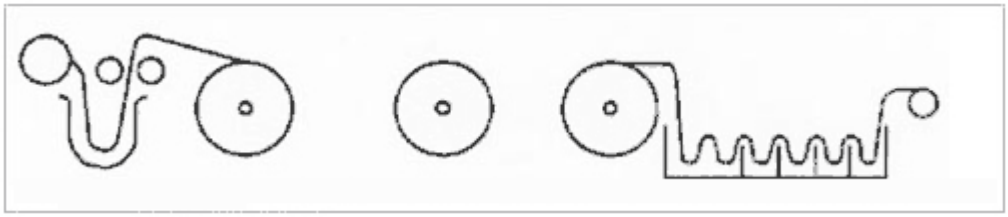
Fig 1.2: Schematic Diagram of a Continuous Dyeing Machine
Source: www.dyespigments.com

Some of the popular methods in continuous dyeing process are Pad-steam, Wet-steam, thermosol dyeing, TAK dyeing, space dyeing, and pad-steam dyeing, long chain warp dyeing etc.

4.3.1 Semi-Continuous Dyeing

In the process of semi-continuous dyeing that consists of pad-batch, pad-jig, pad-roll, the fabric is first impregnated with the dye-liquor, in what is called a padding machine. Then it is subjected to batch wise treatment in a jigger. It could also be stored with a slow rotation for many hours. In the pad-batch this treatment is done at room temperature while in pad-roll it is done at increased temperature by employing a heating chamber. This helps in fixation of the dyes on to the fibres. After this

fixation process, the material in full width is thoroughly cleansed and rinsed in continuous washing machines. There is only one point of difference between continuous and semi-continuous dyeing process: in semi-continuous dyeing, the dye is applied continuously by padding. The fixation and washing remain discontinuous. Liquor ratio in semi-continuous dyeing is not of much importance and is not taken as a parameter. One of the widely used techniques for semi-continuous dyeing process is the Pad Batch Dyeing.A schematic diagram is given here for the semi-continuous dyeing process.



The following table shows some of the important machinery for semi-continuous and continuous dyeing processes.

Table 1.1: Main Features of Continuous and Semi-Continuous Processes

<table>
<tr><th>Make up</th><th>Process</th><th colspan="3">Equipment</th></tr>
<tr><td rowspan="4">Woven and Knitted Fabric, tufted carpet</td><td>Rope</td><td colspan="2">Continuous</td><td>Padding Machine for Piece in rope form</td></tr>
<tr><td rowspan="3">Open width</td><td rowspan="3">Semi Continuous</td><td>Pad batch (or carp-o-roll for carpet)</td><td>Padding Machine+ Washing Machine</td></tr>
<tr><td>Pad batch (or carp-o-roll for carpet)</td><td>Padding Machine+ Washing Machine</td></tr>
<tr><td rowspan="3"></td><td>Pad -jig</td><td>Padding Machine+ Jigger+ Washing Machine</td></tr>
<tr><td rowspan="2">Continuous</td><td>Pad stream</td><td>Padding Machine+ Steamer+ Washing Machine</td></tr>
<tr><td>Pad Dry</td><td>Padding Machine+ Stenter frame+ Washing Machine</td></tr>
</table>

Source: www.dyespigments.com

4.4 Pad Batch Dyeing

Pad Batch Dyeing is one of the widely used techniques for semi-continuous dyeing process. It is mainly used in the dyeing of cellulosic fibre like cotton or viscose (knit and woven fabric) with reactive dyes. Pad batch dyeing is a textile dyeing process that offers some unique advantages in the form of versatility, simplicity, and flexibility and a substantial reduction in capital investment for equipment. It is primarily a cold method that is the reason why it is sometimes referred to as the cold pad batch dyeing.

4.4.1 Workings of a Cold Pad Dyeing Process

The technique or process used in pad-batch dyeing starts with saturating first the prepared fabric with pre-mixed dye liquor. Then it is passed through rollers. The rollers, or padders, effectively force the dyestuff into the fabric. In the process, excess dye solution is also removed. After removal of excess dye stuff the fabric is subsequently "batched". This batching is done by either storing it in rolls or in boxes. It takes a minimum of 4-12 hours. The batches are generally enclosed by plastic films. This prevents absorption of carbon dioxide and water evaporation. Finally as the reaction is complete the fabrics are washed. This is done by becks, beams, or any other washing devices.

4.4.2 Special Features of Pad Batch Dyeing Process

1. Significant cost and waste reduction as compared to other conventional dyeing processes.
2. Total elimination of the need for salt and other specialty chemicals. For example there is no need for anti-migrants, leveling agents and fixatives that are necessary in conventional dye baths.
3. Optimum utilization of dyes that eliminates specialty chemicals cuts down chemical costs and waste loads in the effluent. All this results in a formidable reduction in wastewater treatment costs.
4. Excellent wet fastness properties.
5. Pad batch dyeing cuts energy and water consumption owing to low bath ratio (dye: water) required for the process. This is because unlike other dyeing processes it does not function at high temperatures.
6. A uniform dye quality is achieved with even colour absorbency and colour fastness.
7. As compared to rope dyeing, pad batch dyeing produces much lower defect levels.

8. In pad batch dyeing, qualities like high shade reliability and repeatability are common. This is because of high reactivity dyes with rapid fixation rate and stability.
9. Lastly pad batch dyeing can also improve product quality. The fabric undergoing the cold pad batch dyeing process is able to retain a uniformly coloured appearance. It shows added luster and gives a gentle feel. The fabric gives a brighter look in shades.

SELF ASSESSMENT EXERCISE 1

1. Describe the Batch Dyeing Process:

5.0 CONCLUSION

It could be seen that the understanding of the dyeing mechanism has significantly improved the type of materials resulting from the dyeing processes.

6.0 SUMMARY

In this unit, we have learnt that:

- Today computers are used to control and monitor all aspects of dyeing
- Developmentsin dye chemistry have enabled the man-made fibre to be dyed with better fastness to light and washing, and in an ever increasing range of colours
- Acontinuous dyeing process typically consists of the following. Dye application, dye fixation with heat or chemicals and finally washing
- Pad Batch Dyeing cuts energy and water consumption owing to low bath ratio (dye: water) required for the process
- Pad Batch Dyeing is mainly used in the dyeing of cellulosic fibre like cotton or viscose (knit and woven fabric) with reactive dyes.

7.0 TUTOR- MARKED ASSIGNMENT

i. Describe the mechanism of batch dyeing process
ii. Enumerate the advantages of pad batch dyeing process over other types in the same category.

8.0 REFERENCE/FURTHER READING

Industrial Dyes, Chemistry, Properties, Applications; edited by Klaus Hunger (2003).Wiley-VCH.

UNIT 2 BEAM DYEING MACHINE, HANK DYEING MACHINEAND JIG DYEING MACHINE

CONTENTS

1.0 INTRODUCTION

There is no dirt in the type of Textile dyeing machinery that is available these days to a modern dyeing house. Most of this machineryutilise latest advancement in the dyeing technology to give high capacity dyeing along with uniformity and smooth finishes. For our convenience, we have enumerated below some of the popular categories of dyeing machines although no claim is made here that this list is fully exhaustive.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- Discuss the mechanism of bean dyeing machine
- Identify the main features and process of hank dyeing machine
- Describe the process of jig dyeing machine.

3.0 HOW TO STUDY THIS UNIT

1. You are expected to read carefully, through this unit at least twice before attempting to answer the self-assessment questions or the tutor marked assignments.
2. Do not look at the solution given at the end of the unit until you are satisfied that you have done your best to get all the answers.
3. Share your difficulties with your course mates, facilitators and by consulting other relevant materials particularly the internet.
4. Note that if you follow the instructions you will feel self fulfilled that you have achieved the aim of studying this unit. This should stimulate you to do better.

4.0 MAIN CONTENT

4.1 Definitions

There are still some more efficient dyeing processes which are highlighted below:

4.2 Beam Dyeing Machine

The beam dyeing machine operates with the same principle as that of package dyeing machine. It can be effectively used to dye yarn or fabric. The process works like this: fabric or yarn in open width is rolled on to a perforated beam. The beam then subsequently slid into a vessel that is closed and pressurized. The colour impregnates the fabric as the dye liquor is allowed to go on circulating through the perforations in the beam. Usually the beam machines are designed in such a manner so as to hold a single beam or multiple beams in a batch.

4.3 Batch Dyeing

4.3.1 Features of Beam Dyeing Machine

a. Able to adjust water level in accordance to fabric volume.
b. Even dyeing and superior dyeing quality.
c. Optimized circulation system along with high performance pumps.

4.3.2 Advantages of Beam Dyeing Machine

i. The fabric is put under controlled tension, and is wound on to a perforated beam. This results in elimination of creases from the fabric. It also ensures total control of dimensions of the roll of fabric.

ii. The fabric is held in a fixed position during the process of dyeing. This actually means that there is no application of mechanical action on to the fabric. As shown in the figure, there is no movement of the fabric as the hydrostatic pressure of the pump forces the dye liquor through the fabric roll.

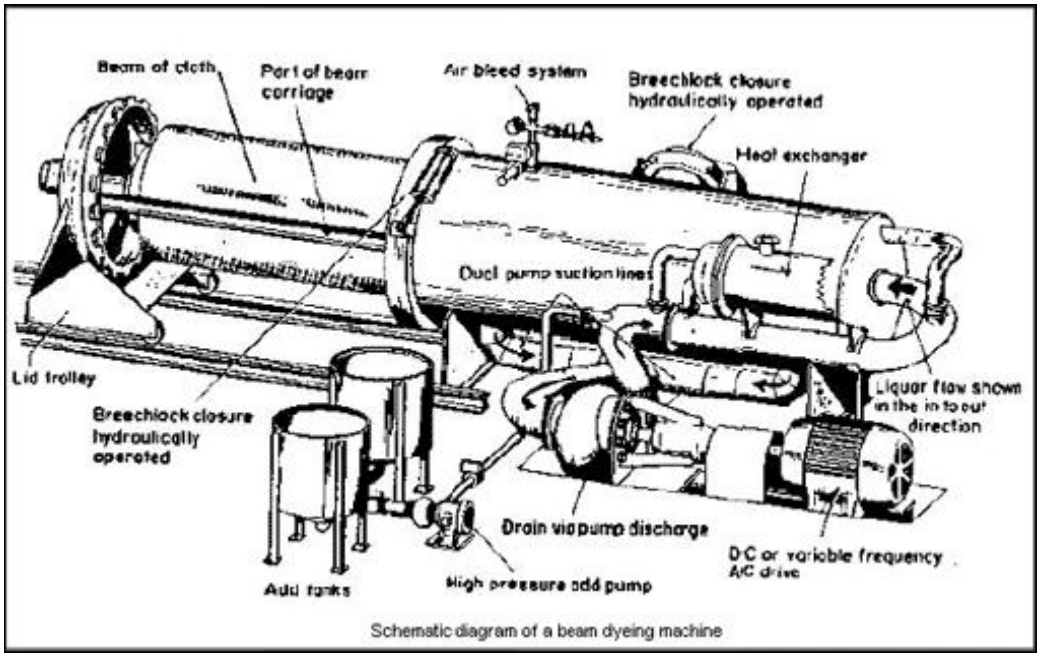


Fig .2.1: Schematic Diagram of a Beam Dyeing Machine
Source: www.dyespigments.com

SELF ASSESSMENT EXERCISE 1

i. Describe the features of a Beam Dyeing Machine
ii. Mention two of its advantages

4.4 Hank Dyeing Machine

Hank dyeing machine is mostly used for dyeing of patterned wool carpets. There are mainly four types of Hank Dyeing machines used. They are the following: single stick Hussong-Type Machines, the double-stick machine, double-stick cabinet machine, and lastly circular carrier machine. Out of this four, the first category of Hussong-Type Machines is the most popular one.

In the Hussong type machines, a hank needs to be hung on removable sticks, from the underside of the dyeing vessel lid. The lid is then vertically lowered onto the dyeing vessel. The dyeing vessel consists of a simple box that has a perforated false bottom. A reversible impeller, which is placed vertically in a weir chamber at one corner of the machine, is used for circulating liquor. Heat is generated by closed steam coils located beneath the false bottom. While on the smaller machines heat is generated by live steam injection.

4.4.1 Features of Hank Dyeing Machine

a. Temperature control is done by electro-mechanical or programmable logic controllers.
b. Machine capacities can range from 10 kg sample machines -1 ton machines.
c. Yarn loads up to 4000 kg can be dyed by coupling together of machines.
d. Typical liquor ratios are 1:15 to 1:25.

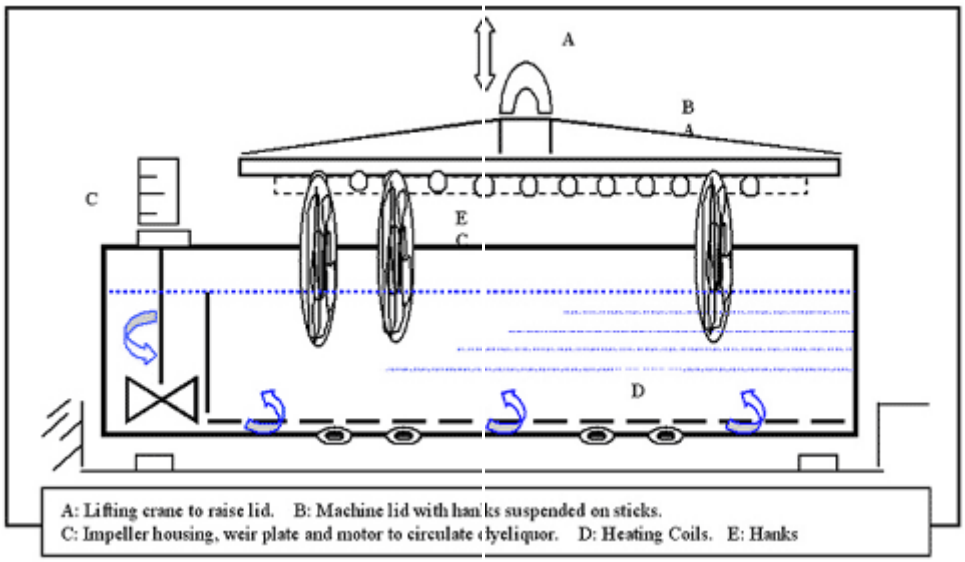


Fig. 2.2: Schematic Diagram of a Hank Dyeing Machine
Source: www.dyespigments.com

4.5 Jig Dyeing Machine

A Jig Dyeing machine is an efficient dyeing technique. It is also known by the name of jigger. Jig Dyeing machine processes fabrics in open width to avoid creasing problems in fabric dyeing. The process works like this. The Jig Dyeing machine operates by transferring the fabric back and forth. This happens from roller to roller via the medium of a

dye bath that is located at the base of the machine. As soon as the second roller gets full, the direction of movement of fabric can be reversed. In Jig dyeing, the duration of the process is measured on the basis of the number of passages or ends of the fabric passing through the dye bath from roller to roller. The end in dyeing parlance is known as the passing of fabric through dye liquor from one roller to the other.

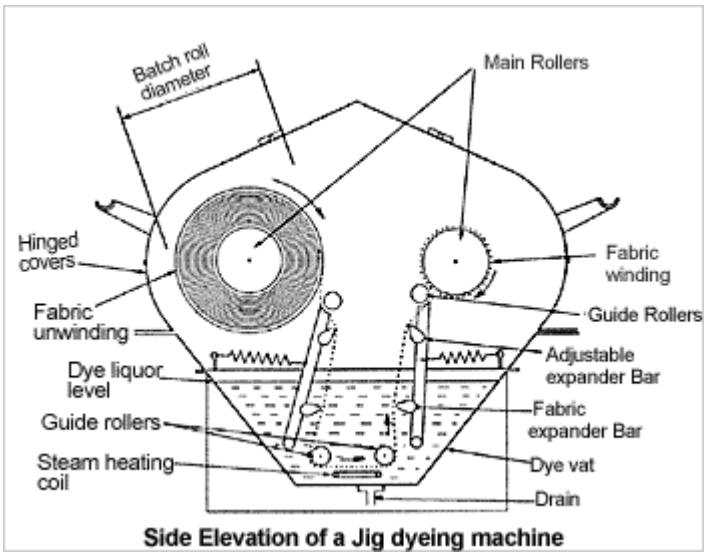


Fig. 2.3: Some Features of a Jig Dyeing Machine
Source: www.dyespigments.com

4.5.1 Types of Jig Dyeing Machine

a. **Atmospheric Jigs**- Atmospheric jigs operate at atmospheric temperatures and pressures. These machines are applied for natural fibres. Here the temperature limit is typically 1000. Centigrade.

b. **High Temperature Jigs**- A high temperature jig functions in the same way as an atmospheric jig, but comes with the addition of a pressure vessel that is designed to function at 1300C. The pressure vessel also helps in having a close control of the dyeing temperature. Typically it is applied for dyeing synthetic fibres.

5.0 CONCLUSION

It could be seen that high technological advancement has produced machinery that are of high quality and gives smooth finishes and beautiful fabrics.

6.0 SUMMARY

In this unit, we have learntthat:

- the beam dyeing machine can be effectively used to dye yarn or fabric
- hank dyeing machines are mostly used for dyeing of patterned wool carpets
- jig Dyeing machine processes fabrics in open width to avoid creasing problems in fabric dyeing

7.0 TUTOR-MARKED ASSIGNMENT

i. With the aid of a simple diagram, describe the operation of a Hank dyeing machine
ii. Enumerate the advantages of both Jig dyeing and Beam dyeing machines.

8.0 REFERENCES/FURTHER READING

Industrial Dyes, Chemistry, Properties, Applications; Edited by Klaus Hunger (2003).Wiley-VCH.

www.dyespigments.com

UNIT 3 JET DYEING MACHINE

CONTENTS

1.0 INTRODUCTION

In the textile industry a variety of machines are used for dyeing. Some of these machines with minor operational modifications can easily accommodate new types of dyes and take advantage of the latest advances made in the dyeing equipment technology.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- Explain the mechanism of Jet dyeing process
- The types of Jet dyeing machine
- Advantages of Jet dyeing process.

3.0 HOW TO STUDY THIS UNIT

1. You are expected to read carefully, through this unit at least twice before attempting to answer the self-assessment questions or the tutor marked assignments.
2. Do not look at the solution given at the end of the unit until you

are satisfied that you have done your best to get all the answers.

3. Share your difficulties with your course mates, facilitators and by consulting other relevant materials particularly the internet.
4. Note that if you follow the instructions you will feel self fulfilled that you have achieved the aim of studying this unit. This should stimulate you to do better.

4.0 MAIN CONTENT

4.1 Definition of Jet Dyeing Machine

In the Jet dyeing machine the reel is completely eliminated. A closed tubular system exists where the fabric is placed. For transporting the fabric through the tube a jet of dye liquor is supplied through a venturi. The Jet creates turbulence. This helps in dye penetration along with preventing the fabric from touching the walls of the tube. As the fabric is often exposed to comparatively higher concentrations of liquor within the transport tube, a small quantity of dye bath is needed in the bottom of the vessel. This is just enough for the smooth movement from rear to front. Aqueous jet dyeing machines generally employs a driven winch reel along with a jet nozzle.

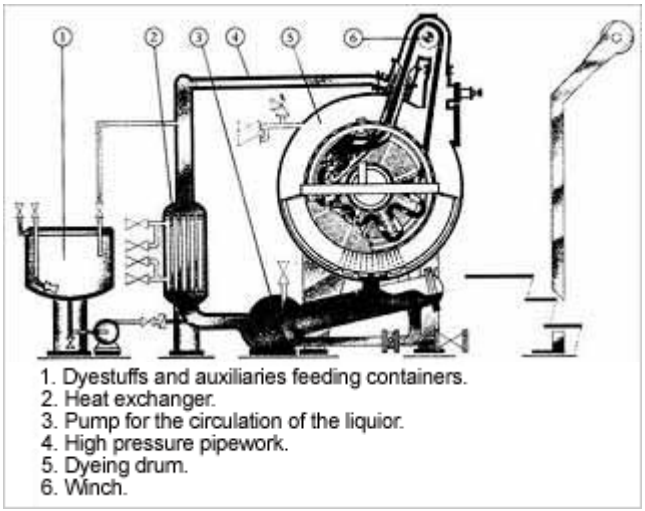


Fig. 3.1: Features of a Jet Dyeing Machine
Source: www.dyespigments.com.

4.2 Types of Jet Dyeing Machine

In deciding the type of dyeing machine the following features are generally taken into consideration for differentiating. They are the following.

- Shape of the area where the fabric is stored i.e. long shaped machine or J-box compact machine
- Type of the nozzle along with its specific positioning i.e. above or below the bath level.

4.3 Overflow Dyeing Machine

Overflow Dyeing Machines are designed for use in delicate knitted and woven fabrics that are made up of natural as well as synthetic fibres. They are also extensively used in the production of carpets. The main difference between jet and overflow machines is that in jet machines the fabric gets transported by a bath that flows at high speed through the nozzle, while in Overflow Dyeing Machine it is the gravitational force of the liquor overflow that is responsible for fabric transportation.

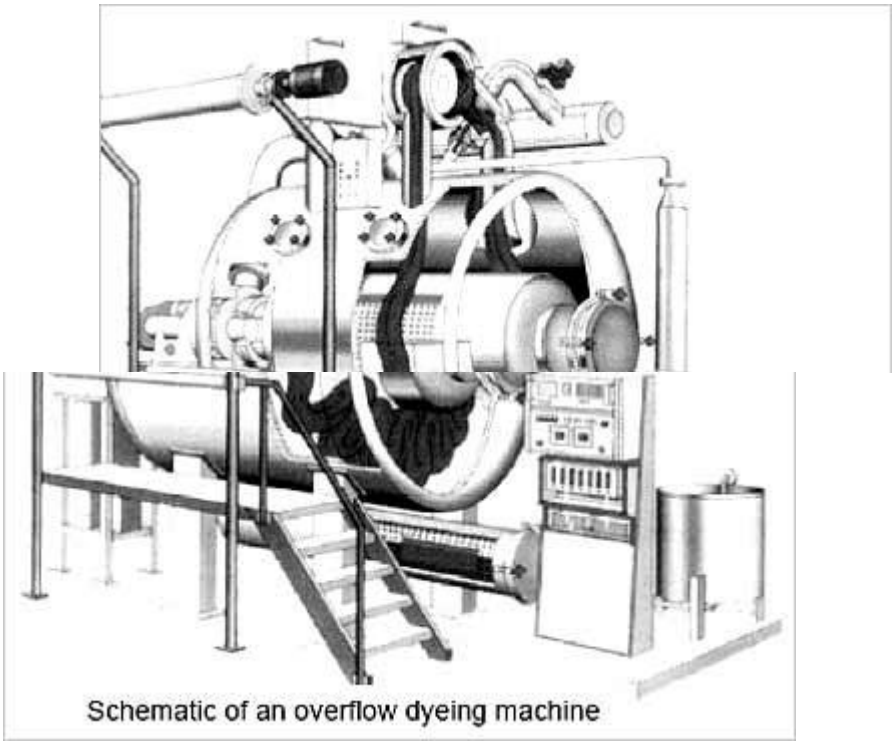


Fig. 4.2: Schematic Diagram of an Overflow Dyeing Machine
Source: www.dyespigments.com

4.3.1 Functioning of an Overflow Dyeing Machine

A typical Overflow Dyeing Machine works like this. A winch that is not motor driven usually is located in the top side of the machine where the fabric is hung. A longer length of textile is made to hang from the exit side of the winch as compared to the inlet side. By applying the force of gravitation the longer length of textile is pulled downward more strongly

than the shorter one. Consequently the fabric is soaked in the bath without any sort of tension.

4.3.2 Advantages of Overflow Dyeing Machine

- **No evaporative losses**- As the dyeing vessel is closed, there is no evaporative losses stemming from the dye bath. Further, depending on the situation the temperature may be raised to more than $1000^{o}C$.
- **No build up of steam condensate in the dye bath**- The latest technology implies that the dye bath gets heated by a heat transducer which is steam driven. This technology apart from being very efficient ensures that there is no build up of steam condensate in the dye bath.
- **Low liquor ratios**- Dyeing is conducted at relatively low liquor ratios, e.g. 10:1 and may be lesser resulting in substantial savings in water and energy.
- Excellent dye liquor contact- Excellent dye liquor contact with the fabric rope results in better and more improved level dyeing.
- **Computer control**- The machines are operated by computers and hence, operator error is eliminated.

4.4 Soft-flow Dyeing Machine

In the soft flow dyeing machine water is used for keeping the fabric in circulation. The conventional difference of this equipment from a conventional jets that operates with a hydraulic system is that the fabric rope is kept circulating during the whole processing cycle (right from loading to unloading). There is no stopping of liquor or fabric circulation for usual drain and fill steps.

The principle working behind the technique is very unique. There is a system for fresh water to enter the vessel via a heat exchanger to a special interchange zone. At the same time the contaminated liquor is channeled out through a drain without any sort of contact with the fabric or for that matter the new batch in the machine.

4.4.1 Key Features of Soft Flow Dyeing Machine

a. Significant savings in processing time.
b. Savings in water that is around 50%.
c. Excellent separation of different streams results in optimum heat recovery and a distinct possibility of further use or a dedicated treatment.

4.4.2 Types of Soft Flow Dyeing Machine

A few of the commercially popular brands along with their particular technical specifications are discussed here. The categories are not exhaustive as such:

(a) **Multi Nozzle Soft Flow Dyeing Machine**
Technical features:

- Very low Liquor ratio - around 1:1 (Wet Fabric)
- Can reach high temp. up to 140°C
- Easily dye 30 to 450 g/mt.sq. of fabrics (woven & knitted fabrics)
- Number of very soft-flow nozzles
- No pilling effect
- Wide capacity

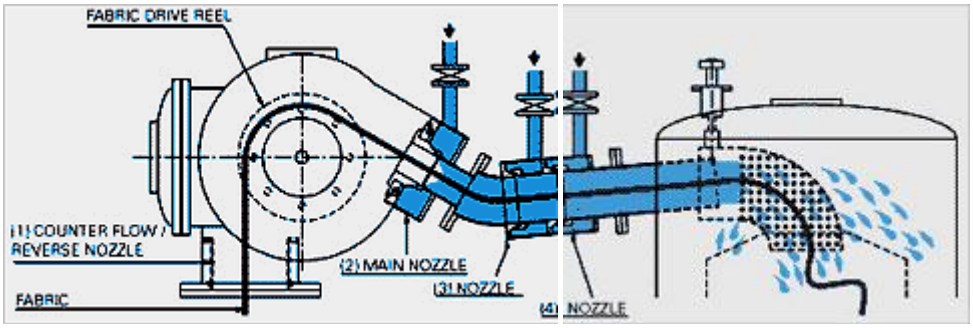


Fig. 3.3: Features of Multi Nozzle Soft Flow Dyeing Machine
Source: www.dyespigments.com

(b) High Temperature High Pressure Soft flow Dyeing Machine
Technical features:

- Compact body made of stainless steel.
- High efficiency heat exchanger for quick heating/cooling.
- Compact body made of stainless steel.
- Heating rate - around 4°C/Min upto 900°C - around 3°C/Min upto 135°C At steam pressure of 6 Bar.
- Cooling Rate- around 4°C/ Min At water pressure of 4 Bar and 15°C.
- Maximum working temp is 135°C.
- Maximum working pressure of 3.2 Bar.
- Control manual as well as automatic.
- Heavy duty stainless steel pump.

4.5 Air Flow Dyeing Machine

This is another development of the very popular jet dyeing machines. The main difference between the Air Flow Machine and Jet Dyeing machine is that the airflow machine utilises an air jet instead of the water jet for keeping the fabric in circulation. Typically the fabric is allowed to pass into the storage area that has a very small amount of free liquor. This results in a reduction in consumption of water, energy and chemicals. The bath level is always under the level of the processed textile. Here the fabric does not remain in touch with the liquor (the bath used is below the basket that holds the fabric in circulation). This invariably means that the bath conditions can be altered without having any impact on the process phase of the substrate.

4.5.1 Advantages of Airflow Dyeing Machine

a. Completely Separated circuit for liquor circulation without getting in touch with the textile
b. Bath less Dyeing operation
c. Rinsing process offers all the added benefits of continuous processing as it is no longer a batch operation
d. Extremely low liquor ratio
e. Virtually nonstop process
f. Comparatively lesser energy requirement due to faster heating/cooling and optimum heat recovery from the hot exhausted dye liquors
g. Reduction in consumption of the chemicals (e.g. salt) dosage of which is based on the amount of dye bath
h. Lesser water consumption savings up to 50% from the conventional Jet dyeing machines
i. Sensitivity towards ecology
j. Economical operation
k. More safety while dyeing

SELF ASSESSMENT EXERCISE 1

1. *Define jet dyeing machine*
2. *Give the key features of soft flow dyeing machine*

5.0 CONCLUSION

There are three types of Jet dyeing mechanisms which are Overflow Dyeing Machine, Soft-flow Dyeing Machine and Airflow Dyeing Machine, which differs in the mode and shape of materials being dyed.

6.0 SUMMARY

In this unit, we have learnt that:

- in the Jet dyeing machine the reel is completely eliminated, thus requiring small quantity of dye bath
- overflow Dyeing Machines are designed for use in delicate knitted and woven fabrics that are made up of natural as well as synthetic fibres. They are also extensively used in the production of carpets
- the main difference between the Air Flow Dyeing Machine and Jet Dyeing machine is that the airflow machine utilises an air jet instead of the water jet for keeping the fabric in circulation.

7.0 TUTOR-MARKED ASSIGNMENT

i. Compare and contrast the advantages of Soft and Air flow dyeing machine.
ii. Mention the types of Jet flow dyeing machine.

8.0 REFERENCE/FURTHER READING

Industrial Dyes, Chemistry, Properties, Applications; Edited by Klaus Hunger (2003).Wiley-VCH.