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Overview of a Knit-Dyeing Factory with Necessary Production Formulas

By Md. Tanjin Amin
Bangladesh University of Engineering and Technology, Bangladesh

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I. Introduction

Bangladesh's first growing economy is the blessing of textile & clothing industries. The economy of Bangladesh was dependent on agriculture solely. But after the introduction of textile sector, the scenario has changed dramatically. The economy of Bangladesh is no longer dependent on agriculture. The agriculture based economy has been shifted to textile based rapidly & massively. Now Bangladesh earns near about 80% of its foreign revenue from this sector. Cheap labor has made it easier to spread textiles based industries. More than 5.7 million of people are working in this sector now. Most of them are women. This sector is helping women to be self-reliant. This short brief on the scenario of textile sector shows how much importance it bears for the economy of Bangladesh. Knit-dyeing factory is the second phase of textile factories. Spinning mills are the first phase and garments are the last phase. But very few of Bangladesh population know about the production procedure in a knit-dyeing factory where fabrics are produced actually. Different production formulas are also unknown to most the persons associated to this sector. So, an effort is made here to make all known about the fabric forming process with mathematical models. It will surely help those who experience the processes; but hardly know the calculative approach.

Author: Department of Mechanical Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh.
e-mail: moshia.nir@gmail.com

II. Knitting

In a fabric processing industry, fabric manufacturing starts with knitting process. Knitting is the process by which yarn turns into fabrics. Knitting is of two types- circular knitting and flat knitting process. Knitted fabrics consist of a series/row of loops, popularly known as stiches. These loops are arranged according to predetermined designed pattern according to the type of fabrics. A new loop is pulled through an existing loop during the progression of series. Active loops are held by the needles of knitting machine. When a new loop comes to the needles, previously active loop is released and the new loop becomes the active loop. This loop forming process goes on and thus fabrics are formed continuously. A sinusoidal wave form is observed in needle movement during fabric formation in circular knitting process. Needles move in circular knitting process while needles remain in fixed position in flat knitting process. Carriages with yarn move in flat knitting process. Yarn may be grey colored or other colored. Grey color is the basic color which comes from spinning mills. But different yarn colors can be achieved by yarn dyeing process. Fiber dyeing is also applied to achieve colored yarn. Single jersey, double jersey/rib and interlock structures are the main three types of circular knitted fabrics. Plane single jersey, lycra single jersey, single lacost, double lacost, honeycomb pique, designed interlock, single jersey fleece, rib, lycra rib, waffle, pin rib etc. are the main derivatives of these three types structure. Flat knitting is done to produce collars and cuffs which are mainly rib or interlock structures. Birdseye, Solid, Tipping, Two Part, Two Part Stripe, Welted etc. are the main derivatives of rib and interlock designs in the flat knitting.

a) Production Calculation Approach in Circular Knitting

No of Needles = (π * Machine Diameter in Inch * Machine Gauge)

Weight of Produced Fabrics = [(No of Needles * Machine RPM * Stitch Length in Meter * No of Feeders * Machine Running Time in Minute * Machine Efficiency * n) / (1.094 * 2.2 * 840 * No of Counts)] kg

n= 1 for Single Jersey Fabrics

n=2 for Rib / Interlock Fabrics

- *Sample Calculation*

Given Data:

Machine Diameter = 26 Inches

Machine Gauge = 24 Needles per Inch

Machine RPM = 26

Stitch Length = 2.65 mm

No of Feeders = 84

No of Counts = 30

Machine Running Time = 8 Hours

Machine Efficiency = 85%

n = 1

No of Needles = (π * 26 * 24)

= 1960

Weight of Produced Fabrics = [(1960 * 26 * 0.00265 * 84 * 480 * 0.85) / (1.094 * 2.2 * 840 * 30*1) Kg = 76.31 Kg

Machine diameter means the diameter of the cylinder used in the machines. Needles are attached in this cylinder. Machine gauge means the number of needles in an inch of cylinder. 840 yards of yarn constitute 1 hank. The number of hanks required to make 1 pound weight of yarn is called the yarn count.

b) Production Calculation Approach in Flat Knitting

Weight of Produced Fabrics = [(No of Needles * Maximum Carriage Speed (m/s) * Stitch Length in Meter * No of Feeders * Machine Running Time in Seconds * Machine Efficiency) / (1.094 * 2* 840 * No of Counts * 2.2 * n)] kg

n = 1 for Single Jersey Fabrics

n = 2 for Rib or Interlock Fabrics

- *Sample Calculation*

Given Data:

Maximum Carriage Speed = 1.2 m/s

Stitch Length = 4.0 mm

No of Feeders = 12

No of Counts = 30

Machine Running Time = 8 Hours

No of Needles = 1120 * 2

Machine Efficiency = 85%

n = 2

Weight of Produced Fabrics = [(1120 * 2 * 1.20 * 0.004 * 12 * 8 * 3600 * 0.85) / (1.094 * 840 * 30 * 2.2 * 2)] kg = 26.04 kg

III. Yarn Dyeing

Yarn dyeing is the process by which colored yarn is obtained. Yarn can be dyed in two processes mainly- hanks dyeing and package dyeing.

a) Hanks Dyeing

Hank dyeing is a simple but time-consuming process. First, the skein of yarn is looped over a hook and washed in water, opening the fibers to receive the dye. It is then dipped into the dye for up to forty-eight hours, washed, and re-dipped. This procedure is repeated several times. Once the desired color is achieved, the yarn is steamed to fix the dye to the fibers. Because it does not use as many chemicals as other forms of dyeing, hank dyeing is less damaging to the material. The final dye colors are also usually richer than those achieved by other dyeing methods.

In hanks dyeing, a batch usually requires 14 hours. So, the capacity of a hanks dyeing machine can be estimated in below formula.

Average Production Capacity = (Batch Loading Capacity * Machine Efficiency * 24 / 14) kg/day.

If a 90% efficient machine has capability of dyeing 245 kg yarn in each batch, average production will be 378 kg/day. However this formula gives idea about average production estimation only. In some cases, nearly 20% more or less production can be got depending on the colors of the yarn.

b) Package Dyeing

Package dyeing usually denotes for dyeing of any type yarn wound on the compressible dye springs/perforated solid dyeing tubes or cones. Yarn dyeing in package form is done at high temperature and under high pressure, with the packages mounted on hollow spindles .These spindles are fixed on the dyeing carriers, which is inserted into the dyeing vessel after closing the lid of the machine, the dyeing liquor is forced through the packages in two way pattern (inside to out and outside to in) and goes on circulating throughout the vessel and yarn. Heat is applied to the dye liquor to achieve the dyeing temperature, time –temperature and flow reversal are controlled automatically. Once full exhaustion is brought about, the carrier of colored yarn is consequently removed from the vessel. Considerable reduction in yarn handling, automatic & accurate dyeing possibilities, reduction in liquor ratio, uniform circulation of liquor, faster dyeing process etc. have given advantage to package dyeing process over hanks dyeing process. Fig. 1 shows package dyeing process.

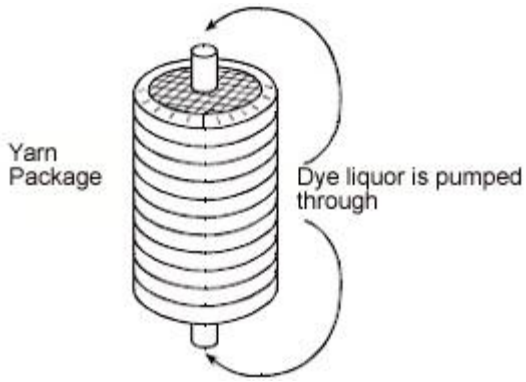

Figure 1 : Package Dyeing Process

In package dyeing, a batch usually requires 10 hours. So, the capacity of a package dyeing machine can be estimated in below formula.

Average Production Capacity = (Batch Loading Capacity * Machine Efficiency * 24 / 10) kg/day.

If an 85% efficient machine has capability of dyeing 500 kg yarn in each batch, average production will be 1020 kg/day. However this formula also gives idea about average production estimation only. In many cases, nearly 10% more or less production has been experienced.

IV. Fabric Dyeing

Fabric dyeing, also known as piece dyeing, is dyeing fabric after it has been constructed. It is economical and the most common method of dyeing solid colored fabrics. The decision regarding color can be made after the fabric has been manufactured. Thus, it is suitable for quick response orders. Dye penetration may not be good in thicker fabrics, so yarn dyeing is sometimes used to dye thick fabrics in solid colors. Various types of dyeing machines are used for piece dyeing. The selection of the equipment is based on factors such as dye and fabric characteristics, cost, and the intended end use.

Most difficult portion of wet processing is to estimate fabric dyeing capacity of a machine per day. This is difficult as different shades require wide range of times to complete dyeing process. For example, white shade requires nearly 4-5 hours whereas navy shade requires 19 hours approximately. Moreover single jersey fabrics can never be loaded in full load batch capacity. If different shades and dyeing operations on different fabrics are done in same machine following empirical relation gives an approximate idea about the capacity of machines per day.

Maximum Fabric Dyeing Capacity = (Maximum Loading Capacity per Batch * Machine Efficiency * 2.5) kg/day.

Some practical observation is compared to this empirical relation in table I considering machine efficiency 90%.

Table 1

Obs. No	Maximum Capacity per Batch (kg)	Maximum Capacity According to Emp. Rel. (kg/day)	Actual Production (kg/day)	Deviation from Emp. Rel.(%)
1	750	1688	1450	14.10
2	500	1125	834	25.86
3	500	1125	2163	92.26
4	250	563	479	14.92
5	60	135	122	9.63
6	360	810	801	1.11
7	1000	2250	1622	27.91

Observation 2 & 3 give some interesting evident. For same batch loading capacity it is seen one machine gives almost 26% less production while another one gives almost double production. In observation 2, machine performed dyeing of different shade on different fabric structures. But in observation 3, machine performed white shade on rib structures mainly. In observation 7, machine did dyeing on rib fabrics of critical shades which caused significant deviation. So, it is clearly understood that dyeing capacity of a machine depends on shade & fabric structure mainly.

V. Mercerizing

Mercerizing is done to both fabrics and threads. Mercerization is a treatment for cotton fabric and thread that gives fabric or yarns a lustrous appearance and strengthens them. The process is applied to cellulosic materials like cotton or hemp. A further possibility is mercerizing during which the fabric is treated with sodium hydroxide solution to cause swelling of the fibers. This results in improved luster, strength and dye affinity. Cotton is mercerized under tension, and all alkali must be washed out before the tension is released or shrinkage will take place. Mercerizing can take place directly on grey cloth, or after bleaching. The factors that affect mercerizing process are-

- Twaddle (Concentration of NaOH)
- Temperature
- Tension
- Time

VI. Singeing

Singeing means burning something. In textile industry, singeing is done to both fabrics and yarn. It is done to make the surface clean & healthy. In yarn singeing, yarn passes through the burner in a very rapid speed and unwanted raised fiber ends are burnt. In fabric singeing, at first fabric surface is brushed slightly to raise the loose fibers. Then fabrics pass through the copper plates or burning flames in such a speed that loose fibers are burnt without damaging the fabrics. After this fabrics enter into a desizer or water bath to prevent any afterglow as a result of singeing.

VII. Reeling, Hanks to Coning, Soft & Hard Winding

Reeling is done to make suitable hanks for hanks dyeing process.

Hanks to coning are done after hanks dyeing process. It is a process by which hanks are winded around required cones.

Soft winding is done before package dyeing. In this process, yarn is rolled against tubular cones in such a way that liquor can pass through the packages uniformly.

Hard winding is done after package dyeing. In this process, yarn is rolled against tubular cones very tightly.

Yarn weight can be related using following formula.

Winding Rate of Yarn = [Winding Speed in m/min. * 60 * No of Cones * No of Plies / (No of Count * 1.094 * 840*2.2)] Kg/hr

- *Sample Calculation*

Given Data:

Winding Speed = 600 m/min

No of Cones = 230

No of Counts = 30/2

Winding Rate of Yarn = [600 * 60 * 230*2 / (30 * 1.094 * 840 * 2.2)] kg/hr = 273 kg/hr

Yarn singeing production process can be calculated using above procedure also.

VIII. Slitting

Slitting is a process that is applied for cutting the tubular fabric through the intended break Wales line on lengthwise direction prior to stenter processing. During slitting, it is required to be aware about the cutting line otherwise, fabric faults can be occurred there. Slitter machine is used for tubular knit fabric to make it in open form. In open form fabric finishing line; slitter machine is used after hydro-extractor, de-watering and drying machine. So, the main objectives of slitting are-

- To open tube fabric according to specific needle mark.
- To prepare the fabric for next stentering process.

IX. Drying

Drying is done after de-watering of fabric. In textile finishing unit, dryer uses for dry the knit, woven fabrics and dyed yarn. But the drying process and drying mechanism of yarn and fabrics is different from one to another. The main functions of a textile dryer is to dry the textile fabrics. Drying is defined as a process where the liquid portion of the solution is evaporated from the fabric.

X. Stentering

Stenter is used for open form fabrics. Cotton fabric shrinks widthwise and weft distorted due to bleaching and dyeing process. The main functions of the stenter are-

- Heat setting is done by the stenter for lycra fabric, synthetic and blended fabric.
- Width of the fabric is controlled by the stenter.
- Finishing chemical apply on fabric by the stenter.
- Loop of the knit fabric is controlled.
- Moisture of the fabric is controlled by the stenter.
- Spirility controlled by the stenter.
- GSM of the fabric is controlled by stenter.
- Fabric is dried by the stentering process.
- Shrinkage property of the fabric is controlled.
- Curing treatment for resin, water repellent fabric is done by the stenter.

Amount of stentered fabrics can be calculated using the following formula.

Stentering rate = (Average Width of Fabric in meter * Average GSM of Fabric in kg per sq. meter * Fabric Finishing Speed in meter per minute * 60) kg/hr

a) Sample Calculation

Given,

Before Width of Fabric = 143 cm

After Width of Fabric = 155 cm

Average Width of Fabric = 149 cm = 1.49 m

Before GSM of Fabric = 194 gm/m2

After GSM of Fabric = 184 gm/m2

Average GSM of Fabric = 189 gm/m2 = 0.189 kg/m2

Fabric Finishing Speed = 20 m/min

Production rate = (1.49 * 0.189 * 20 * 60) kg/hr

= 337.932 kg/hr

XI. Compacting

Compactor is a textile finishing machine which is designed especially for compacting 100% cotton knitted fabric like jersey, pique, interlock, plush, rib and sinker etc. as well as cotton blended fabric in rope form, changing the loft and dimensional stability of the fabric and presenting it to plaited form. By the compactor machine, compacting is done for control the shrinkage of the fabric. Fitted with two felt/rubber/metal compacting units, make it easier to obtain top quality fabrics with minimized shrinking nature and a soft fluffy hand. Compactor machines are of two types-

- Tubular compactor
- Open compactor

Main functions of compactors are-

- GSM control of the knitted fabric. For high GSM, overfeed is increased and fabric width is decreased. For low GSM, overfeed is decreased and fabric width is increased.
- Control shrinkage
- Twisting control
- Increase smoothness of fabric.
- Heat setting is done of fabric etc.
- Fabric width is controlled by the compactor.

The main processes in compacting process are-

- The fabric is fed through the guiding system and stretcher which then takes the fabric through the steam box onto the felt of the twin compacting units.
- Width control through a stepless, adjustable fabric spreader driven by variable speed motor for distortion-free fabric guidance.
- Over feed roller controls overfeed.
- Brush pinning arrangement for controlling pinning.
- Steaming with a condensate-free steam box which is easily operated and completely made from stainless steel. The Steaming Device has sliding shutters that allow steam to flow only as per the width of the fabric.
- Compacting through two Nomex felt belts.
- Calendaring while passing between the felt belt and the heated shrinking rollers.
- At the fabric delivery, the machine is equipped with a precision plaiting device with its platform. The height of the platform is controlled automatically and is adjustable according to the plaited fabric height.

Amount of compacted fabrics can be calculated using the same formula that is used to calculate stentered fabrics amount.

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