1. INTRODUCTION TO KNITTING

Knitting is as popular method of fabric construction, as weaving. The popularity had grown since last two decades, and in recent years knitting has overtaken over weaving. The major reasons are:

i. Now all type of yarn including manmade can be used for knitting a garment.

ii. There has been more versatility in production of different fabrics. Now almost all type of suiting, shirting, or furnishing fabrics can be made from knitting.

iii. The characteristics of easy to wash-n-wear, wrinkle free, stretchable fabric, make it best for casual wear, inner wear, ladies wear and sportswear.

iv. Also the loops generated help in more warm wear and absorbency purpose.

1.1 Comparison of Knitted fabric with Woven fabric

1.1.1 **Similarities of Knitted fabric and Woven Fabric:**

1.1.2 Differences of Knitted fabric and Woven Fabric:

Sr. No.	Knitted fabric	Woven fabric
1	Weft knitted, or knitted fabric can be made from a single yarn.	Woven fabric can be made from two sets of yarn, warp and weft.
2	Knitting is defined as intermeshing of loops.	Weaving is defined as interlacement of warp and weft.
3	A knitted fabric is stretchable. It thus forms shape fitting property. Hence it can be used for innerwear, sportswear, and ladies garments.	Woven fabrics are rigid, and cannot be stretched.
4	Knitted fabrics are less elastic. They recover little less to their original position after they are stretched.	Woven fabrics have higher elasticity. It means when stretched they recover to almost the original position.
5	The structure due to loop formation is such that there are no wrinkle formations in a knitted fabric. It does not require ironing, and is ready to wear after washing only.	Woven fabric, especially the warp is highly twisted, and is harsh in feel. Woven fabrics need to ironed after washing.
6	A knitted fabric has disadvantage. If a single loop or yarn is broken then the whole fabric starts to open, developing a hole in fabric.	Any breakage in woven fabric can be mended, and it does not spread very easily to whole fabric.

7	Knitted fabrics are difficult to tear. The pressure applied is distributed to the whole fabric.	Woven fabrics can be torn easily like a paper, by holding between two fingers.
8	The yarns used for knitting are less twisted, and thus produce a fabric that is soft in feel.	The yarns used for knitting are more twisted, and thus produce a fabric that is soft in feel.
9	A knitted fabric with same wt./yard is more fuller.	A woven fabric with same wt./yard is more intact than a knitted fabric.
10	Knitted fabric has loops. Air can pass very easily through them.	Woven fabrics are less permeable to air. Air cannot pass through the fabric easily.
11	However the structure also helps to make air packets. This helps in retaining warmth of the body. Hence the knitted fabrics are also used for sweater.	No warmth retaining quality is there in woven fabric due to its structure.
12	Knitted fabric can be made on simple machines without any preparatory process.	Woven fabric can need preparatory processes like winding, warping, sizing.
13	The loop structure of knitted fabric help in absorbency of water.	Due to more twisted and a tight structure these fabrics are less absorbent.
14	Design on knitting can be changed very easily.	To change design on a weaving machine, or loom, warp beam is to be changed if it is warp wise. If the change is in weft, then design on shedding mechanism (dobby, jacquard) is to be changed. It requires extra effort.
15	Thus this can be started with very less investment and space.	Hence a lot of investment of money and space is required for its set up.

In brief knitted fabric is extensible (shape fitting property), wrinkle free, wash and wear, softer, fuller, thicker, less bending length, casual wear, less elastic. It has disadvantages like laddering, bagging, or deformation, difficult in cutting and tailoring

1.2 Comparison of warp and weft knitting

1.2.1 Similarities of Knitted fabric and Woven Fabric:

1.2.2 Differences of Knitted fabric and Woven Fabric:

Sr. No.	Warp Knitting	Weft Knitting
1	Single yarn can make the whole fabric.	The number of yarns required is equal to the number of needles.
2	The fed material is cone or cheese.	The fed material is by beam.
3	The fabric is constructed weft wise, or course wise.	The fabric is constructed warp wise, or wale wise.
4	Needles knit sequentially, that is needles knit one after the other.	Needles knit concurrently, that is all needles knit together.
5	The production is less than warp knit.	The production is very high than weft knitting.
6	The fabric prepared may be low quality than warp knitted.	The fabric prepared of very even quality.
7	Production speed decreases with increase in the design.	Production speed do not decreases much with designing.
8	No preparatory process is required. So the extra investment of machine, space, man power is not there.	Preparatory process is required. So the extra investment of machine, space, man power is not there.
9	Machines are low cost	Machines are high cost.
10	A less skilled labour can operate.	A skilled labour is required to operate.
11	Due to these reasons the fabric produced is less in cost.	Due to these reasons the fabric cost is high.
12	The fabric is more stretchable width wise and length wise than warp knit.	The fabric is less stretchable width wise and length wise than weft knit fabric.
13	Difficulty in cutting and tailoring.	Easy in cutting and tailoring.
14	Loop structure:	Loop structure:

1.3 Definitions in Knitting

In case of weaving we have warp and weft thread. But in case knitting we call them course or wale. Knitting is done by formation of loop or stitch. *Loop* or *stitch* is the basic or fundamental unit of a knitted fabric. It is formed by bending of yarn. *Knitting* is defined as intermeshing of loops. A row of loops intermeshed along the fabric width or in horizontal direction is called as a *Course* (not weft). A row of loop along the fabric length or in vertical direction is called as a *Wale* (not warp). Knitting is done by two ways, course wise as well as wale wise. If knitting is done along the width or the fabric, or course wise then it is *Weft knitting*. If knitting is done along length of the fabric, or wale wise then it is called as *Warp knitting*. Now a day weft knitted was done till last few years. Now warp knitting has also taken up. The properties of warp knitted fabric lies between a weft knitted and a woven fabric structure.

Warp knitting
A method of making a fabric by normal knitting means, in which the loops made from each warp are formed substantially along the length of fabric.

Weft knitting
A method of making a fabric by normal knitting means, in which the loops made from each weft are formed substantially along the width of fabric.

Single jersey fabric
A weft knitted fabric made on one set of needles.

Double jersey fabric
A weft knitted fabric made on two sets of needles, usually based on rib or interlock gaiting, in manner that reduces the natural extensibility of the knitted structure. These fabrics can be non-jacquard or jacquard.

Course
It is a row of loops across the width of the fabric. Courses determine the length of the fabric, and are measured as courses per centimeter.

Wale
It is a column of loops along the length of the fabric. Wales determine the width of the fabric, and are measured as wale per centimeter.

Stitch density
It is the number of stitches per unit area of a knitted fabric (loops/cm2). It determines the area of the fabric.

Stitch length
It is the length of yarn in a knitted loop. It is the dominating factor for all knitted structures. In weft knitting, it is usually determined as the average length of yarn per needle, while in warp knitting, it is normally determined as the average length of yarn per course.

Yarn linear density

It indicates the thickness of the yarn and is normally determined in tex, which is defined as the mass in grams of 1 lm of the material. The higher the tex number, the thicker is the yarn and vice versa.

Overlap
Lateral movement of the guide bars on the beard of hook side of the needle. This movement is normally restricted to one needle space. In the fabric a loop or stitch is also termed as overlap.

Underlap
Lateral movement of the guide bars on the side of needle remote from the hook or beard. This movement is limited only by the mechanical considerations. In the fabric, it is the connection between stitches in consecutive courses in a warp-knitted fabric.

Tightness factor
A number that indicates the extent to which the area of a knitted fabric is covered by the yarn. It is also an indication of the relative looseness or tightness of the knitting.
(K=TEX1/2.1 -1)

Area density
A measure of the weight of the fabric (g.m -2)

Cams
Knitting cams are the simplest design element on any knitting machine. Depending on the machine design these are fixed, adjustable or exchangeable. Different designs can be produced by combination of knit, tuck and miss cams.

Long and short butt needles
The principle of butt length is that the element with the longest butt is always contacted first as a cam is brought into operation and the shortest butt is only affected when the cam is fully in action. This method employs different butt lengths and cam thickness.

Different butt height (Multi Cam tracks)
These are used to obtain a large number of small designs. Each needle has a top butt at a common height and each needle also retains one of four available butts which will travel in its track. The needle will be lifted by the lower butt to tuck or clear by the individual cam acting upon it each feeder.

Plating
The plating yarn carrier/ feeder is designed to take advantage of the fact that two yarns which are feed simultaneously into the hook of the needle tend to appear on different sides of the loop surface according to their initial placing in the needle. When placed into the hook, the yarn which is placed higher appears in the rear of the combined loop structure. The yarn placed lower dominates at the face side of the combined loop.
Two different yarns (of different properties) are supplied separately to influence their relation position on surface, but knitted together. Normally used to produce fancy color effects, modify the wearable properties, lace work etc. the yarn positioned towards the needle hook with is visible on back surface of fabric.

Racking
Flat knitting machines are capable of producing a unique range of racked structures based on the facility of racking one needle bed by one or more tricks with respect to other in either direction as and when required. The structure created by this principle is called as then racked stitch.

Tracking elements
With this facility a knitting machine can select needles to transfer this loops to needles in the opposite bed, thus providing increased design possibilities for purl effects, cable and other cross over stitches, selvedge edge shaping, a hole or lace design, etc.

Drop stitch
A stitch dropped accidently causes a fault in the fabric in the form of a ladder, but a controlled procedure in which loops are dropped is used to increase the size of certain selected loops and so to pattern the fabric.

Pattern wheel
It is simple device which occupies a minimum space and easy to operate. The technique makes use of one pattern wheel at each feeder. Metal bit is placed in the wheel trick which lifts the needle to knit/tuck heights. Two types of bits can be used for knit and tuck selections. Where the trick is left blank the needles are left down. Each pattern wheel makes one row of design and the depth of the pattern is equal to the number of pattern wheels in the machine.

Pattern drum
Each drum has a matrix of holes, in each of these holes a pin (peg) can be inserted. In this case a pattern jack, lying behind is deflected and presses its adjoining selector into the cylinder. The needle arranged above the selector would then make no stitches. The absence of a pin means that the jack is not deflected, it is now possible for the selector to run with its lower butt and guide the needle above it into knitting position.

Pattern comb
This system provides knit, tuck and miss selections by a using a pattern comb at each feeder. Half tooth produces tuck whereas full tooth makes float on the fabric. Fully removed tooth guides the selector to move the needle to knit height. Maximum number of wales and courses in the design will be equal to the number of tooth in the comb and total numbers of feeders in the machine.

Laying-in
A yarn is laid inside the knitted structure but never formed into a knitted loop. It can modify the properties such as stability, elastic, stretch and recovery, weight, surface appearance, handle, surface properties. Normally the yarn due to certain properties like thickness according to gauge, weak in strength, in elastic in characteristics cannot be knitted normal fashion and is thus put in.

Open work structures
Laces, inner and outwear of ladies garments. Plush and pile constructions for swimmers, bathing clothes, Housecoats

1.4 Knitted stitches

The stitch or loop is the fundamental unit of knitted fabric. There are 3 type of stitches.

1.4.1 Knit stitch

This is the normal stitch that we see in a knitted fabric. It has a face and a back. The side of the fabric that appears to be normal is the face side of the loop, and that appears to be back of the fabric is formed by back loops. The combination of these *face* and *back loops* help in making of different basic knitted fabrics.

1.4.2 Tuck stitch

This stitch is formed when the last loop is help along with the next loop. It means two loops of different courses are held together. This help in developing derivatives of different of basic knitted fabrics.

1.4.3 Float or Miss Stitch

It is formed when a stitch is not formed. In this case wither the new stitch is formed on its place by use of another yarn, or the loop from the last course that is below it takes its place. Like a tuck stitch, it also helps in developing derivatives of different of basic knitted fabrics.

1.5 Basic Knitted fabrics

While discussing various stitches, we had discussed that various stitches forms different type of knitted fabrics. Combination of face and back loops of a simple knit stitch form the different type of knitted fabrics, and its combination along with tuck and float stitches form different derivatives of these knitted fabrics. Normally there are four type of knitted fabrics, plain, rib, purl and interlock. The basic knitted fabrics are:

1.5.1 Plain knitted fabric

It is the simplest and most widely used knitted fabric. It is developed by using knit stitches side by side, horizontally as well as vertically, to form knitted fabric. It is made on single set of needles. The fabric can be made on flat knit or in circular (tubular) form. Since this is the only knitted fabric made in single layer, it is also called as *single jersey fabric*.

1.5.2 Rib knitted fabric

This fabric can be developed by knitting face and back loop alternatively. It means that odd number of wales (vertical column of loops) will be made of face loops, and the next or even wales (vertical column of loops) will be of back loops. This will be made on two sets of needles, and is thus in two layers. It is called as *double jersey knitted fabric*. One knitting face, and other knitting back loops in the same row, means face and back loops alternately. This fabric shows horizontal lines (vertical gap type), and is very stretchable widthwise. All extremities in knitted fabrics like collar, end of the sleeves, and the bottoms of the T-shirts, sweaters are made of rib. It is extremely stretchable widthwise. Due to this, it is also used for ladies wear and shape fitted fabric.

1.5.3 Purl knitted fabric

This fabric is made by knitting alternate courses (horizontal row of loops) of face and then back loops. It appears like purl or as if the fabric is being worn from reverse. The machine used is has two beds fitted at 180^{o} to each other and forms a double jersey fabric.

1.5.4 Interlock knitted fabric

This fabric is combination of two ribs fitted or fixed in a single fabric. A rib fabric shows vertical line type gaps. The other rib fabric fits into the first one in this gap, and thus appear as a plain fabric from the front and the back. This fabric is therefore equal to two fabrics in thickness and weight.

2. WEFT KNITTING MACHINES

There are two types of knitting, weft and warp knitting. Weft Knitting machines are classified as per the bed shape in which needles are fitted. There are basically two types of knitting machines, *flat bed knitting machine* and *circular bed knitting machine*. The numbers of beds are either one or two. A single bed is required to knit the simple plain knitted structure. Only *plain knitted fabric* is made on single bed knitting machine, and thus form only one layer of loops. It is thus called as *single jersey knitted fabric*. The bed is named as *single flat bed* in flat bed. In circular knitting machine this single bed is named as *cylinder*.

Other knitted structures are in two layers. Thus two beds are required for knitting other knitted fabrics or structures, i.e. rib, purl, or interlock. In all other fabrics (rib, purl, and interlock), the loops used for fabric formation are constructed on two beds, that is in two layers, and are thus referred as *double jersey knitted fabrics*. In flat bed knitting machines, these are called as V-shaped flat bed. L-shaped flat bed (for rib and interlock). For making a purl fabric, the two beds in flat bed are at 180º. The two beds in circular knitting machine is named as *cylinder* and *dial*. Both beds are at right angle to each other in all type of machines.

Warp knitting machines are of two types, *tricot and raschel*.

2.1 Elements or Parts of knitting machines

Knitting elements are the main part of the machine. For the weft knitting machine the knitting elements essentially consists of

i. Needles
ii. Sinkers (for the single jersey machine only)
iii. Cylinder
iv. Dial (for double jersey machine)
v. Cams

A knitted fabric is made by *needle* movement. The needles move up and down vertically. While going up they clear the old loop to make the fabric, and then while coming back they hold the new yarn from the yarn feeder, to make next loop. The movement of the needles is vertical but this movement is generated by the *cam*. The cams moves in horizontal direction, and has specific space cut between them. The needles have a hook at the top for formation of loop, and had a protruding surface at the bottom, called as the butt portion. This protruding portion, or the butt passes through the gap of the cam. This cut makes the butt move up and down, and also the needle. The yarn is fed from the *creel*. In case of weft knitting the *feed package* is cone or cheese. In warp knitting it is a beam. The yarn is then passed through *guide*, and then through *tensioner*. The material or yarn is fed to the needles by *yarn feeder*. The needles are fitted into the *bed* of the machine. Bed may be *flat* or *circular*. In case of circular knitting machine if set of needles is single, then the bed is called as *cylinder*, and the second bed is called as *dial*. The needles move up and down to form a stitch. This movement to the needles is provided by the *cam*. The fabric made is then held by weight or take down mechanism.

2.1.1 ii. Sinker

One of the most important element after needles. It is a thin metal strip adjusted between each needle to hold down the stitch and adjust stitch length also (the web portion). The belly is used to hold the fabric that is knitted. The butt portion provide the to & fro horizontal motion with the help of sinker cam.

It performs one or more of the following function:

- Loop formation
- Holding down the loop
- Knock over of loop

The sinker has two main functions and these are:

- To hold the fabric loop in a given position whenever the needles rise.
- To provide a surface over which the needles draw the loops.

Other advantages of using sinkers include:

i. The control exerted by the sinker allows minimum tension on the fabric thus producing a good quality fabric with even loops.
ii. Fine adjustments in quality and those required in the knitting of certain difficult tarns and structures are possible.

- Facilitates the setting-up of the machine after a partial or full press-off (after the latches have been opened manually).

2.1.2 iii. Cylinder

The circular needles bed in which the needles are disposed vertically is called the cylinder. The slots (grooves) cut in the cylinder to receive needles are called "tricks." The cut (gauge) of circular knitting machine is based on the number of "cuts" (or) slots in the space of one circumferential inch on the periphery of cylinder [outer surface of the cylinder]. Machines are built as low as 4 needles per inch to as high as 28 to32 needles per inch. The gauge of the cylinder can be approximately decided of the count and the material of the yarn is known. Thus for single cotton yarn

Count=$cut^2/6$

Cylinder diameters vary according to the type of goods to be manufactured. The diameter varies from about 1cm to about 75 cm. Small diameter machines have less number of feeds than big diameter machines. The speed of the machines is about 20 to 40 rpm for a 60 cm diameter machines.

2.1.3 iv. Dial

The dial is another needle bed used only in double jersey knitting machines. The dial is a steel disc in which slots are cut radiating from the centre. Hence it is housing for horizontal needles. The number of slots per unit space conforms to the cylinder gauge in most places**.**

2.1.4 v. Needle cam

The cams are made of hardened steel and each needle movement is obtained by (needle) means of cams acting on the needle butts. The tracks in the cams are formed by screwing small steel parts with the cam plate in the desired manner. These steel parts are called as cams. Different types of cams are screwed for giving movement to the needle. The upward movement of the needle is obtained by the rising cams. Cams controlling the downward movement of the needles are called stitch cams. *Stitch cam* controls the length of yarn to be drawn or the loop length. Now, the stitch cams are held in a cast iron removable section screwed to the cylinder cam ring and are adjustable in a vertical direction. *Guard cams* helps to keep the needle butts in their race way (track). *Running cam or up throw cam* keep the needle butts at a low level until they meet the next rising cam. It helps the needle to return to rest position to relax for new cycle.

2.2 i. Needles

There are three types of needles in common use today in knitting industries.

1. Latch needle
2. Spring bearded needle
3. Compound needle

2.2.1 Latch needle

It is mostly widely used in weft knitting. Also called as “self actuating” needle because they require no external element (sinker) to close the hook. The swing of latch solves the purpose. It consists of a hook at the top of the needle, and the space between the hook and the needle stem can be bridged by a latch which swings freely. Latch needles are given individual movement sliding in grooves, and these grooves are normally called ‘tricks’. The stem is a straight portion of the needle with a protruding butt, some distance from the end of the needle. The reciprocating movements to the needles are given through this butt part of the needle.

Main parts of Latch needle

Hook: draw and retain new loop.

Slot: that receives latch blade.
Rivet: used to retain the latch blade.
Latch blade: help in knock-over of old loop.
Latch spoon or cup: helps to cover the gap between the hook tip and stem to knock-over old loop
Stem: holds the last loop of fabric during rest or clearing position.
Butt: converts rectilinear motion to reciprocation motion from cam to needle
Tail: extension of the butt

Knitting cycle of Latch Needle

A latch needle knitting cycle can be explained by 5 different positions.

Rest position: Needle hook is in level of top merge of trick. The loop previously formed is in hook and needle is in position to move up.
Running position: The needle gets upward movement with the butt by pressing it against clearing cam. The latch opens. The old loop starts descending on to latch.
Clearing position: The needle is at top most position. The old loop is cleared from latch and is on to stem. The hook is ready to take new yarn.
Yarn feeding: The needle starts to descend. The hook holds the new yarn got past by the feeder. The old loop starts to slide up closing the latch and new yarn inside the hook.
Knock-over position: The needle descends to the downward position and draws the loop length. The old loop first closes the latch with new Yarn inside it that is ready to form loop. The old loop is knocked over the hook portion of needle, converting the fed yarn into loop.

2.2.2 Spring bearded needle

Bearded needle was the needle used in first knitting machine known as stocking frame. Needles having a long terminal beard that can be flexed by an action known as pressing. It can be made from single piece of metal in a machine gauge as fine as 60 needles per inch. This is the oldest needle which is simple in construction and cheap in manufacture

The bearded needle, which was invented by the reverend William lee in 1859, consists of hook with the top curved part continued downwards and finished with a point. It is this downward continuation that is called the beard. Opposite the point of the beard is a groove cut into the needle stem. This is called the eye of the needle.

Main parts of spring bearded needle
Head:
Beard:
Eye or groove:
Stem:
Butt or shank:

Knitting cycle of Spring bearded needles

Clearing position: The old loop is round the stem of the needle and the yarn is fed at A higher point on the needle stem and kinked into a loop. Each wale in the fabric requires a separate needle.

Feeding position: The needle is now moved down until the newly formed loop is under the beard and this time the beard is pressed. A metal bar is used to exert pressure on the needle beard so that the point is pressed into the eye of the needle. Closed and the old fabric loop moves to the outside of the needle beard. When the fabric loop has been launched in this position the pressure on the beard can be released.

Knock over position: The needle now moves to its lowest position drawing the new loop through the old fabric loop which is now cast-off. The needle now returns to start another course.

2.2.3 Latch needle v/s Spring bearded needle

Latch needles are thick end can be used for coarse gauge, rigid with high speed, the swinging movement of needle becomes difficult. Latch needle takes longer time to knit the loops. Chances of accumulation of fluff or lint are there on latch. But they are self actuating and do not require external agencies for knocking over of loop. They are expensive to manufacture.

2.2.4 Compound needle

Both bearded and latch needles were found to have limitation in their operating speeds. Speed of bearded needle is restricted because of an external element, presser where as the swinging action of the latch causes damage to the yarns at very high knitting speed. To overcome these difficulties many attempts were made to develop a compound needle though no type has been found suitable in weft knitting but it is gaining popularity in warp knitting machines. The compound needles which comprises

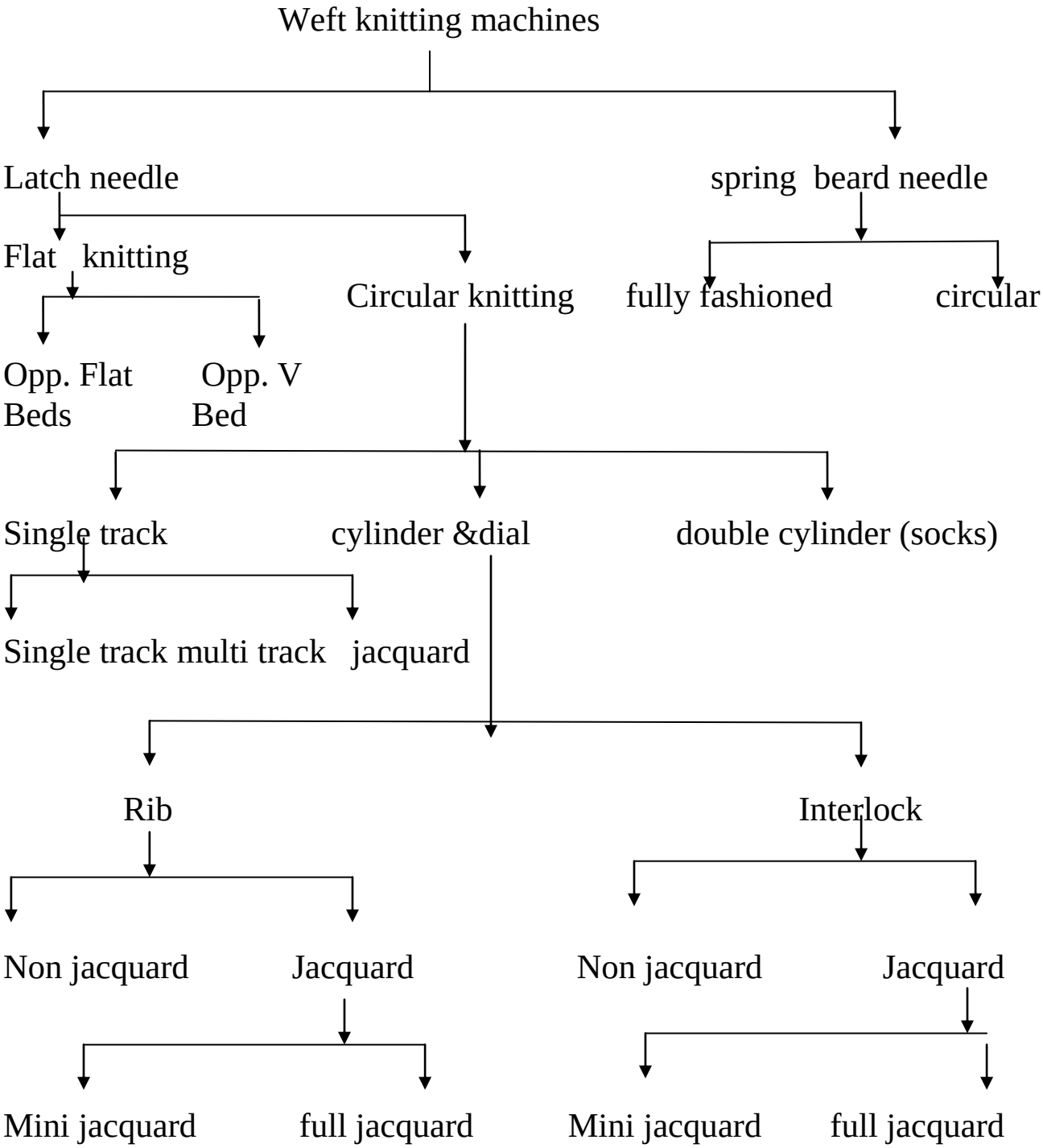
two parts- the hook and tongue. These two parts rise and fall together but as the hook moves at a faster rate, it is open at the top of rise and closed at the bottom of fall. There are two types of compound needle in common use today: (1) tubular pipe and (2) open stem pusher type needles. Tubular pipe needles consists a hollow steel tube in which the tongue member is inserted and the tongue slides inside the tube. In open stem pusher type of compound needle the tongue slides externally along a groove on the edge of the hook member. Compound needles combine the merits of both latch and bearded needles with less strain on the yarn and higher speeds. These needles are expensive to manufacture because each part requires separate and precise control from the drive.

Main parts of compound needles

Hook:
Tongue:
Stem:
Butt:

Knitting cycle of Compound needle
Clearing position: The old yarn is cleared. The tongue is in the stem. The needle starts to descend. The yarn feeder approaches with yarn.
Yarn feeding position: The feeder passes the descending hook, providing it with the yarn. The tongue starts to rise.
Knock-over position: The new yarn is pulled to maximum.

2.3 Classification of Weft knitting machines as per needles



2.4 Circular weft knitting machines

They are basically classified into four types according to the type of knitting element used and their arrangement.

1. Plain knitting machines (single jersey) used for producing plain-knit fabrics.
2. Rib knitting machines (double jersey) used for producing rib knit fabrics.
3. Interlock knitting machines (double jersey) used for producing interlock fabrics.
4. Purl knitting machines (double jersey) used for producing purl fabrics.

2.4.1 The continuous rotary motions of circular knitting machine enable two types of machine to be made. They are

- Revolving needle bed machines with fixed cam tracks.
- Revolving cam box machines with fixed needle beds.

There are two types of machine movements in circular knitting machines

Revolving needle or cylinder machines

The cams are stationary and the cylinders with trick having needles fitted in it are moving in the grooves (path) of the cams. The butt portion of the needle moves in this trick getting reciprocating motion.

Most circular machines are of the revolving needle bed type. Here the needle bed, fabric and the take up system rotate while the yarn packages, cam box and yarn supply system remain stationary.

Reciprocating or rotating cam box machines

The bed with the needle is stationary in horizontal movement and the cam revolves. In this case the yarn feeder or creel must move with cam. Mostly used system but not preferred in large diameter and multi creel supply.

The raising or running cam helps the needle to either tuck or clear the loop. On Machines of the revolving cam box type fabric and needle beds remain stationary while the bobbin frame rotates with the yarn guides and cam boxes.

2.4.2 Passage of material through a circular knitting machine

The given diagram shows the general description and passage of material through a circular knitting machine with revolving needle beds. The machine frame is the body of the machine. The needle beds are supported in the centre of this frame.

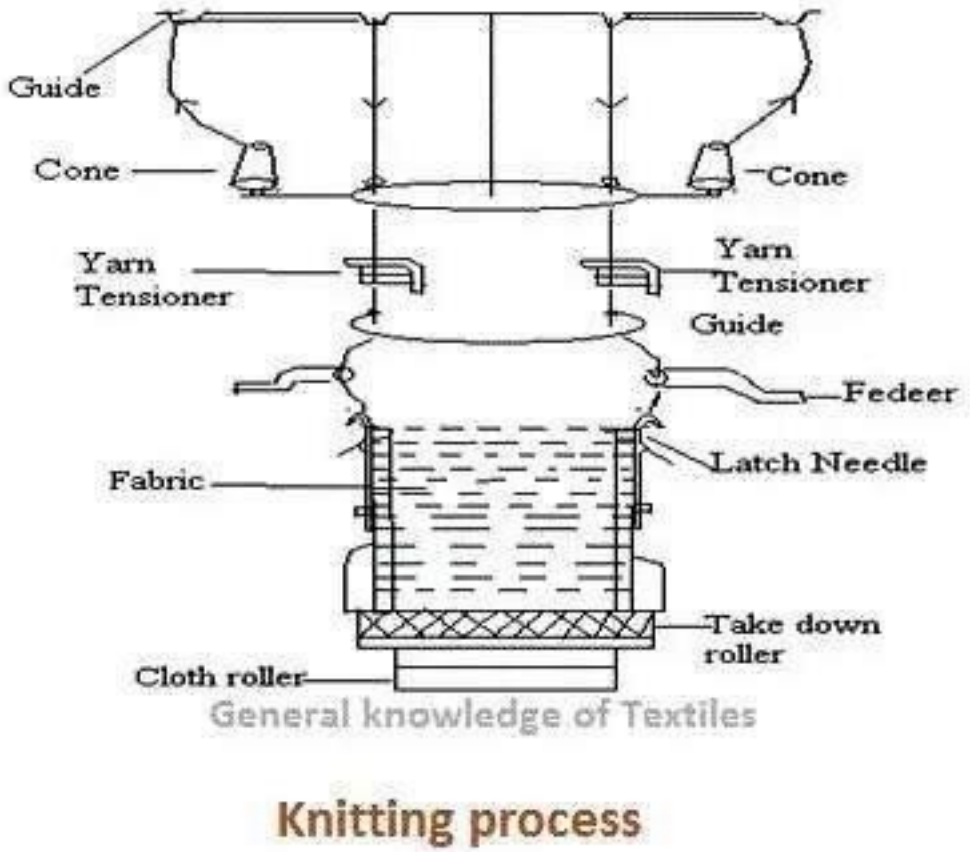


Diagram of Circular knitting machine

Single knitting is fitted with a sinker and cylinder beds whereas rib and interlock machines have both a cylinder and a dial. The needles are inserted into the tricks of the needle beds. The needles are controlled by fixed cams.

The yarn packages are set at upper part of the machine on the bobbin stand. The yarn is unwound overhead, following the packages axis to the yarn break stop motion placed at the top of machine. The yarn then returns down through a guide to the middle stop motion. Then the yarn is delivered to the yarn guides by a yarn feeding system. Now the yarn guide feeds the yarn to the knitting elements where the fabric is being knitted. Then the knitted fabric goes down inside the cylinder towards the centre of the machine.

A spreader fixed inside the fabric tube prevent the formation of creases, as the fabric is drawn into the take down device which provides the tension necessary for stitch formation. The fabric is collected on a roll winding mechanism.

2.5 Flat bed knitting machine

These machines are commonly used for producing weft knitted fabrics. In the open width form. The basic types of flat knitting machines available are:

1. Rib flat knitting machines ("V" Bed machines)
2. Purl flat knitting machines.

Initially hand operated flat knitting machines were developed and its production were very low hence power driven v-bed flat knitting machines are mostly used in the industries. This machine are used for producing collars, cuffs, sweater, pull, over, mufflers and head caps, from cotton and woolen or acrylic yarns.

2.5.1 Passage of material through V-shape flat bed knitting machine

Yarn path : flat machines are usually equipped with a bobbin stand(2) and support(1) mounted behind the needle bed. The bracket (3) is fitted with the following

A yarn guide ring(4) directly above the package support

A yarn tensioning device(5)

A knot stop motion(6)

A Spring arm tensioner usually coupled with a yarn break stop motion(7) and delivery pot-eye(8)

The yarn is then feed to the yarn guide (9) at the end of the yarn carrier (10).

Before the yarn reaches the yarn carrier as it passes through a cymbal tensioner which may be adjusted to provide the correct knitting tension. A stop motion is used here to stop the machine if there is any big knot or slub in the yarn.

The spring tensioning arm comprises a steel arm fitted with a pot eye through which the yarn passes. This eye is always drawn upwards by the adjustable spring tension on the rod and serves to absorb the excess yarn feed as the carriage reaches the end of its traverse. This is being done in order to maintain the required constant tension on the yarn as the carriage reverses its movement.

Needle arrangement

A rib knitting machine must have two sets of needle which are interposed between each other in "rib gating". Each set of needle is supported by one needle bed and these are designated the front needle bed and back needle bed respectively. In each bed the needles are placed in parallel tricks found on a flat metal plate. The needle hooks face outwards from the needle bed and the needles can move freely up and down in their tricks.

A plate called a needle cover bar prevents the needles being tilted by the fabric take down tension. The blade separating two adjacent needles is called the trick wall. At the end of each trick wall a tooth called a "knock-over comb". At the lower end of the needle a spring maintains the needle butt at a fixed height. These springs are also held in position by a covering bar. The maximum working width on a flat knitting machine is equal to the needle bed width.

Cam arrangement

In the knitting machines the needle bed is stationary and hence the needles are vertically displaced within its tricks to form the loops. For raising the needles a triangular shape cam (upper part is smoothly grounded) is arranged so that it points upwards, while its base is just below the level of the needle butts. When this cam is moved from left to right the needle butts will be pushed upwards.

When the needles have been raised the stitch cam (1) acts on the needle butt causing them to be lowered. Having knitted by moving the cams from left to right, knitting must now take place as the cams move in the opposite direction. To allow this another stitch cam (2) must be added to the cam system and is placed to the right of the raising cam. These three cams are mounted in a carriage that can slide along the needle bed in both directions. Further two auxiliary cams (a) and (b) are also fitted in the front bed cam system to delay the knock over of front bed needles. In order to control the needles in both beds simultaneously two sets of cams must be employed. These cams are mounted on a carriage and slide over both needle beds as the carriage makes its traverse Only one end of yarn is required to form each course so one yarn carrier will suffice when producing rib fabric.

Stitch cam setting

The stitch length determines the fabric tightness. The stitch length is governed by the position of the stitch (knock-over) cam. If this cam is set at the very low position then the loops drawn by the needles are long. Conversely a high stitch cam setting results in the needles drawing short loops.

The level of the stitch cam is adjusted by translating the entire cam up or down a slot. For this purpose the cams are fitted with studs that fit in the slots and allow this movement. During the cam displacement, side of the cam that acts on the needles always remains in the same plane and the cam track width is not reduced.

The fabric take down roll

On simple machines, take down tension is applied to the fabric by suspending a comb and some weights from it. More sophisticated have mechanical take down rollers. Take down tension is designed to exercise a tension on the loops held on the needles to ensure correct knock-over and to avoid problems like difficulty in maintaining the fabric level, raising and lowering of loops along with the needle movement.

Cross section of machine

In cross section, the front (1) and back(2)needles beds supported by the machine frame (3) .The guide bars on which the yarn carrier travels are illustrated at (4) and (5). The carriage moves along the tracks (6) and (7).The carriage consists of two cam plate blocks (8) and (9), joined by the bridge (or blow10). The carriage guide studs (11) are shown at base of each needle bed. The yarn carrier is indicated by (12).

Inclination of needle bed

The front and back needle beds are inclined and form and angle between 90 to 140 degree depending on the manufacture. This angle facilities the feeding of yarn and give greater stability to the carriage.

Yarn carrier (Low bow Machine)

Figure shows the yarn guide (1) mounted on the driving box (2) which slide on guide bars (3). The guide of the yarn guide is fixed on the guide bar of the carriage (4). Two conditions must be met.
-feeding must be delayed with respect to axis of symmetry of the cam system.
-At the end of each course the yarn guide and carriage must be independent of each other.
The pump is fixed to the carriage at the central axis of one cam plate. Its acts on the shoulders of the guide box during its traverses and drive the carrier.

The figure shows the font view of the yarn carrier box. Considered a carriage traverses from right to lift. The piston acting on shoulder A will drive the yarn guide and its box. During left to right traverse the piston drives the box by acting on B. If a release plat (3) is positioned on the guiding bar facing the yarn guide, the piston will follow inclined plan (4) and release the yarn carrier. Similar plates positioned at each end of the knitting width so that the yarn guide may be inactivated within a few centimeter of the operating needles.

3. KNITTED FABRICS

Loop or the stitch is the fundamental unit of a knitted fabric. Use of different stitches makes different types of fabrics and their derivatives.

3.1 Types of stitches

Except the normal face or back loops, the two loop stitches that change the structure and properties and develop variety in knitted fabrics are float and tuck stitches.

In a needle there is loop inside, and the new yarn is fed in to make a new loop. The combination of old and the new loop can form 4 combinations with old loop knocked over & new yarn fed (knit), old loop remains in the hook & new yarn fed (tuck), old loop remains in the hook & no new yarn fed (float), and old loop knocked over & new yarn not fed (not possible).

3.1.1 Knit stitch

This loop is produced by clearing the old loop from the hook or latch by raising needles and feeding the new yarn to form new loop on the same needle. If the loop is drawn towards the face of the fabric, it is called as face (front) loop, and the loop drawn at the back side is known as the Reverse (back) loop. This stitch is used for plain fabric in all knit structures. Loose and tight knitting can be done by increasing or decreasing the loop length by adjusting the stitch cam known as quality setting.

3.1.2 Tuck stitch

It is formed when the needle receives the yarn to form loop, but does not pull through the previous loop. The needle is not raised sufficiently so that the old loop is not cleared but raised enough to receive newly fed yarn.

Characteristics of tuck stitches

i. Reduces the fabric length and lengthwise elasticity.
ii. Increases the fabric width and widthwise extensibility.
iii. Increases the fabric thickness and weight.

iv. Produces three dimensional effects on the fabric. Produces open and more porous fabric.
v. Show faint diagonal line effect on the surface of the fabric.
vi. Assumes an inverted u shape configuration.

Uses *of tuck stitches*

i. To shape the fabric.
ii. To increase weight and thickness of fabric.
iii. Used to developed load resistance.
iv. To develop surface appearance. To arrest floating loops at the back of fabric.

3.1.3 Float stitch

A float stitch is formed when the needle retains the old loop in the hook and also do not receive the new loop. It is mainly used for surface appearance. The unwanted coloured yarn is hidden behind the face loop. It can be done at a maximum of six adjacent needles. Make fabric thinner of less loops, narrower, less extensible because less yarn is available with the loops, lighter.

Characterstics of float loops are:

i. Reduces the fabric width and widthwise elasticity.
ii. Improves the fabric stability.
iii. Reduces the fabric thickness and weight.
iv. Show faint horizontal line effect on the fabric.
v. Assumes U shaped configuration.

3.2 Knitted fabric representation

A Stitch is the basic repeating unit in any knitted structure. It should be possible to represent the stitch notation in order to record in a readily understandable form. The layout of the stitches will form the basic repeat of a particular structure.

There are four ways to represent the knitted structures as given below:

i. Verbal representation.

ii. Diagrammatic
iii. Graphical representation (or) line diagram.
iv. Symbolic

3.2.1 Verbal representation

This method is the simplest one where the name of the structure is sufficient to describe the structure or where a simple description of the knitting elements and knitting sequence is sufficient to visualize the construction. It describes the structure in a definition form and so the technical knowledge of knitting is absolutely essential. Example- knit, tuck, float, face loop, back loop..

3.2.2 Diagrammatic representation

It shows the actual picture of the stitch. But this is one the most difficult and time consuming method of representation. So other methods had been drawn to simplify the drawing of the complex structures.

Knit stitch: Face loop

Back loop

Tuck stitch:

Float stitch:

3.2.3 Graphical representation

This method is very useful for simple structures and could be easily understood by a beginner. A double line representation may be used to show the dimension of the knit yarn, but preferably a single line is used to represent the structures, as this method is less time consuming.

Knit stitch: Face loop

Back loop

Tuck stitch:

Float stitch:

3.2.3 Symbolic representation

This shows the movement of the loop around the needle.

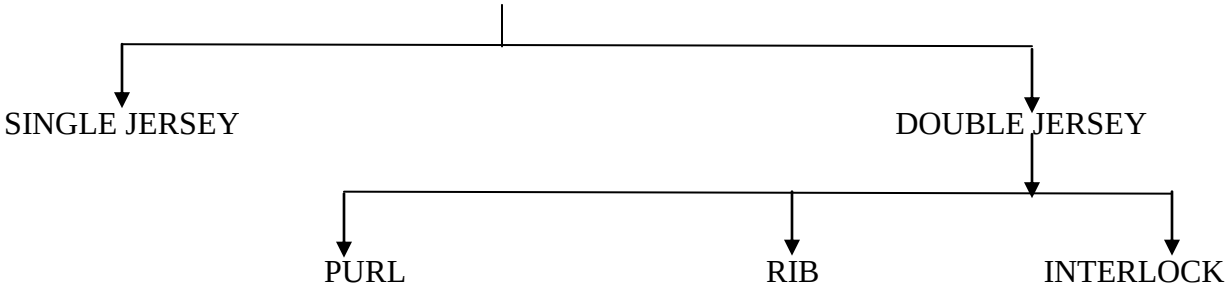
Knit stitch: Face loop

Back loop

Tuck stitch:

Float stitch:

3.3 CLASSIFICATION OF WEFT KNITTING



3.3.1 Single Jersey fabric (Plain)

In single jersey knitting, only one set of needles are used. Needles are arranged in a needle bed which may be either flat or circular. These machines have one needle for every wale in the fabric and between each needle there is a sinker, which has two functions: to hold the fabric down when needle rises and to provide a surface over which the needle draws the loop.

3.3.2 Double Jersey fabric

Double knit fabrics are weft knitted structures which require two sets of needles either in circular or flat forms. Double jersey fabrics such as rib and interlock can be produced on both flat and circular machines. In the case of circular machines the second needle bed is equipped in the form of a dial i.e. a flat disc is placed on top of the cylinder. In the case of purl machines the two needle beds can be flat or circular equipped with double ended latch needles. In the circular version of the purl machines the second set of needles is in the form of a second cylinder superimposed above the first.

3.4 Plain knitted fabric

3.4.1 Characteristics of plain knitted fabrics

i. It is produced on a single set of needle.
ii. The structure is simplest and most economical in weft knitting.
iii. It can be un roved from the course knitted last.
iv. The structure is of nearly two yarn diameter thick.
v. When the fabric is cut, the fabric curls towards back from sides.
vi. It has maximum covering power.
vii. It can be stretched in most directions upto40% depending on yarn parameter.
viii. It can recover 40% of stretched width wise depending on yarn parameters.
ix. The count suitable for knitting.
Ne =G2/18 G (Gauge/N.P.J.)
x. Uses: Knitted footwear, all types of fully fashioned garments, body panels of garments

3.4.2 Knitting cycle of plain knitted fabrics

i. *Rest position:* The loop previously formed is in the hook and the needle is in the position to move up.
ii. *Running position*: The needle gets upward movement with the butt by pressing it against clearing cam. The latch opens. The old loop starts descending onto the latch.
iii. *Clearing position*: The needle is at top most position. At this stage the needle ascends to clear the latch of the loop and the hook is ready to take the new yarn.
iv. *Feeding position*: The needle starts to descend. The hook holds the new yarn. The old loop stars to slide up closing the latch and new yarn inside the hook.
v. *Knocking over position*: The further descend of the needle results in the old loop being disengaged from the end of the hook and also a new loop being formed at the end of hook.

3.4.3 Ornamentation of plain knitted fabrics

i. *Horizontal strips* can be produced by using different color yarns on different feeder or different courses.

ii. *Zig-zag effect* can be produced by using differently twisted (s-z) yarns in different courses in groups. It is visible wale wise

iii. .*Use of fancy yarns* like Grandville, knops, corkscrew, gimp yarns can be used to replace simple yarn to produce a fancy sort of fabric.

iv. *Plated jersey fabric* by using two different yarns with one yarn being visible on the surface.

3.4.4 Derivatives of plain knitted fabrics

S. no.	Name of derivative	Feed no. 1	Feed no. 2	Feed no. 3	Feed no. 4
i.	Fred Perry	K T	K K	T K	K K
ii.	Single Lacoste	K T	T K	K T	T K
iii.	Double Lacoste	K T	K T	T K	T K
iv.	Weft locknit	K M	K K	M K	K K
v.	Cross Miss	K M	M K	K M	M K
vi.	Birds Eye	K M	K M	M K	M K
vii.	Mock Rib	MMM KKK	KKK MMM	MMM KKK	KKK MMM
viii., ix.,x.	Twiil effect				
xi.	Simple Crepe				
xii.	Cellular Blisters				
xiii.	Accordian Fabric	KKKKK	KMTMK	KKKKK	----

The Graphical representation of the following is shown below

K – Knit M – Miss T- Tuck

X

*

Knit and Tuck combinations

i. Fred perry

X	X
*	X
X	X
X	*

ii. Single lacoste

*	X
X	*

iii. Double lacoste

*	X
*	X
X	*
X	*

Knit and Miss combinations

iv. Weft locknit

X	X
	X
X	X
X	

v. cross miss

	X
X	

vi. Bird eye

	X
	X
X	
X	

vii. Mock rib

X	X	X			
			X	X	X
X	X	X			
			X	X	X

Knit and Miss/ Knit miss & Tuck (Twill effect) *combinations*

viii.

		X	X
	X	X	
X	X		
X			X

ix.

	*	X
*	X	
X		*

x.

	*	X	X
*	X	X	
X	X		*
X		*	X

Extra

xi. Simple crepe

X	X	*	X
X	X	X	*
	*	X	X
*	X	X	X

xii. cellular blister

X	X	*	*
X	X	*	*
X	X	*	*
X	X	*	*
*	*	X	X
*	*	X	X
*	*	X	X
*	*	X	X

xiii. Accordian Fabric

X	X	X	X	X
X		*		X
X	X	X	X	X

Accordian Fabric is a combination of Knit, tuck and float. The design is produced by selection of knit and float. The floating threads are held in place on technical back by tuck stitiches.

a. Straight accordian: Every odd needle is had an extra butt in line with a tuck cam i.e. the tuck are normally made on alternate with those of knit and float on each course.

b. Alternate accordian: This has a better distribution of tuck stitiches. Here, odd needles tuck at odd courses while the even needle tuck at even courses. It means that tucking occurs on same needles at alternate courses.

Both of these (above) have tuck stitch together causing distortion.

c. Selected accordian: The accordian fabrics not falling in the above two categories falls in it. the design is developed by knit and float, and elimination of float is achieved by use of tuck stitch.

3.5 Rib knitted fabric

Rib requires two sets of needles operating in between each other, so that wale of face stitches and wale of reverse stitches are knitted on each side of the fabric.

3.5.1 Characteristics of rib

i. The fabric has a vertical cord like appearance as the face loop wale tends to move over and in front of the reverse loop fabric.
ii. The stitch lies in two planes.
iii. The simplest rib fabric is 1x1 with technical face appearance on both sides
iv. It is produced on two sets of needles.
v. The fabric is twice as thick and half the width as plain structure in relaxed state.
vi. However, it has twice as much as width wise recoverable stretch.
vii. The fabric is balanced and has no tendency to curl without cut.
viii. They have an extensibility, better elasticity and retain warmth properties.
ix. Count suitable for rib knitting can be

Ne =G2/8.4 G= needle/inch

x. Uses: Due to unroving and elastic properties it is used in borders and colors, tops of socks, cuffs of sleeves, border of garments or in cardigans. They are also used for preparing ladies tops winter wears as they give shape fitting properties.
xi. Rib structure representation

3.5.2 Knitting cycle of rib

Running position: The hooks of cylinder and dial hold the old loop. The loop starts to descend onto stem.

Clearing position: Needles on both beds are moved further away to clean the plain and rib loops formed in the previous cycle with a time log.

Yarn feeding: The yarn is received first by one needle (cylinder) and then by other hook in the dial. The old loop in the stem starts moving up and about to close hook with latches.

Knock over cylinder: The old loop is knocked over the cylinder while the dial needle follows.

Knock over dial: The adjacent dial needle now knocks over the old loop in order to convert the yarn fed to new loop.

3.5.3 Derivatives of rib knitted fabrics

Simple Variations

i. Swiss rib

2/2

X	X	O	O

ii. English rib

2/3

X	X	O	O	O

iii. Derby rib

6/3

X	X	X	X	X	X	O	O	O

Knit and tuck combinations

iv. Half cardigan or royal rib

It is produced by knitting face wale on one set of needles and by tucking on alternate course on back wale. The fabric is wider as no legs, and thicker than 1x1 rib

X	*	X	*
X	O	X	O

Needle 1 2 3 4

v. Full cardigan or polka rib

It can be obtained by tucking on alternate courses in both the face and back wale i.e. when one set of needles (either front or back) is tucking the other set will knit. For the next course, the other set will yuck, while rest will knit.

*	O	*	O
X	*	X	*
.	O	*	O
X	*	X	*

Both of these types are used to produce body panels and sleeves of heavier type of knitwear. The other popular variations are next two.

vi. Fisherman knit (on 2x2 rib)

X	X	*	*
X	X	O	O

vii. Sweater stitch

*	*	X	X
X	X	*	*

Knit and Float combinations

viii. Half milano

	O
X	O

ix. Full Milano

X	
	O
X	O

x. Swiss double pique: It is very stable, used extensively in women's dresses and suiting. It is prepared on four courses and a narrower and heavier fabric is produced.

\

			O
X		X	O
	O		
X	O	X	

xii. French double pique: It is modified (from) form of Swiss double pique. In second course only even number dial needle knit while in fourth course only odd numbers dial needle knit.

	O		
X		X	O
			O
X	O	X	

Knit, tuck and float combinations

xiii. Knop effect:

X	O	X	O
X	O	X	O
X		X	*
X		X	*
X		X	*
X		X	*
X	O	X	O
X	O	X	O
X	*	X	
X	*	X	
X	*	X	
X	*	X	

3.6 Interlock Fabric

The fabric is obtained by interlocking of two 1x1 rib structures such that in a wale, the face loop of one fall directly in front of the back loops of the other fabric, and the case is reverted in the next wale.

3.6.1 Characteristics of Interlock fabric

i. The fabric is a combination of two 1x1 rib structure embedded into each other in an alternate sequence.
ii. The two courses (for different set of needles) of loops show wale of face loop on each side of fabric, exactly in line with each other. The reverse loop of other set is thus hidden.
iii. It is a double jersey fabric.
iv. The fabric shows only technical face of plain fabric on both sides.
v. The machine has two feeders; two sets of needles (short and long), two different can tracks.
vi. There are two feeders running simultaneously, one helping to produce 1x1 rib on one set (long) of needles, and the other simultaneously allowing other (short) set of needles to prepare 1x1 rib so that they show being embedded.
vii. The fabric cannot be unroved from the yarn knitted last and is ladder resistant.
viii. A balance fabric, with smooth stable structure.
ix. It doesn't cure from edges.
x. The fabric is heavier, narrower and thicker than rib of equitant gauge.
xi. Productivity is half to that of rib.
xii. Horizontal stripes are produced if two consecutive feeders have the same coloured yarn and vertical stripes will be produced if odd and even feeders have different yarn colour.
xiii. End uses: Undergarments, outer wears, such as polo shirts, sports jackets ladies sweat and children sleep wears.
xiv. Properties of Interlock fabric: Firm fabric, lustrous, soft look, strong, tendency to acquire original width, heavier, ladder resistant and balanced does not cure form edges.

3.6.2 Derivatives of interlock fabric

Simple Variations:

i. Eightlock

It is n produced by intermeshing of two 2x2 rib used in cuffs and bathing suits.

Knit and tuck combinations:

ii. Single pique or cross tuck

It is produced by putting a tuck cam on every third feeder (i.e. 1^{st} and 4^{th}) only on dial needles. The fabric is wide by 15% to normal interlock

iii. Taxi pique

Tucks on both cylinder and dials on every third feed. The fabric is wider and bulkier.

iv. Pin tuck

Tuck with two consecutive feeders in every six feeds only on back needles.

Knit and miss combinations:

v. Cross miss

The fabric has miss stitch on every third feed on dial needles. It is lighter in weight.

vi. Panto di roma (4 feed)

vii. Panto di roma (6 feed)

viii. Piquette

Reversible wefts miss structure with light cord effect.

ix. Cortina

x. Bourrelet fabrics

It has pronounced horizontal cord at regular intervals produced by knitting excess courses on cylinder needles. The cord course may be of different colour than ground. Interlock rather than rib bourrelet is preferred because it is softer, smoother, has more regular surface, and less elasticity.

a. Jersey cord b. super nova

3.6.3 Production of Interlock fabric

It can be produced on circular knitting machines (with two tracks cut in cams of cylinder and dial) or double system v-bed machines. Two separate sets of long and short needles run in each of the cam tracks feeding simultaneously one after the other.

a. There should be two beds with alternatively one long and one short needle, adjacent to each other. The long set of needles of one bed should face short set of needles so that only one of the two can knit at any feeder.

b. One cam system controls knitting at one feed and other at next feeder.

c. The alternatively set needles work for one feeder either long or short.

Cams and needle diagram

3.7 PURL FABRIC

In a purl fabric courses are knitted with face and back courses alternately, or horizontally. A 1x1 purl structure has both face and reverse loop stitches in the same wale.

3.7.1 Characteristics of Purl fabric

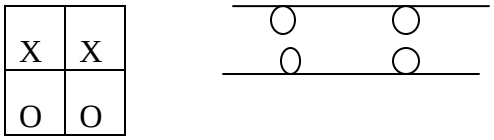
i. The fabric produces a course wise effect.

ii. In 1x1 purl fabric alternative courses are knitting in opposite direction i.e. 1 face and 1 back .

iii. The appearance is like technically back of a knitted fabric.

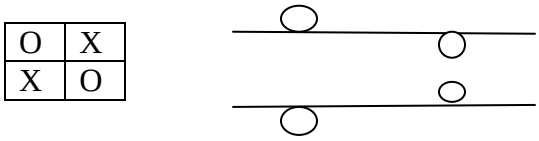
iv. Both face and back loop are seen in a single wale.

v. The fabric produced has a balanced structure and has no tendency to cure at edges.
vi. The fabric has a good cover.
vii. Thickness is double to the plain knitted fabric i.e. same as rib structure.
viii. It has double lengthwise elasticity and widthwise elasticity same as plain knitted fabric. Fabrics are full, lofty and soft handle.
ix. Thickness is double to the plain knitted fabric i.e. same as rib structure. In relaxed state, the face loop will cover the back loop thus increasing the thickness.
ix. End uses: Children wear, sports shirts, goes sweaters.
x. Design of Purl



3.7.2 Derivatives of Purl fabric

Moss stitch



3.7.3 Production of Purl fabric

There are two types of pure knitting machines. Flat Purl, that has two horizontally opposed needle beds, and circular purl machines with two superimposed cylinders on above the other.

It usually made on a machine fitted with double ended needle shows the cross section of the knitting elements of purl machine. The two needle beds are set at 180* to each other i.e. in a straight line, with a gap between, straddled by a double ended latch needle. There is cam carriage which moves from right to left and left to right alternately, above the needle beds. The carriage has cams which activate the needles in knitting action.

The pure knitted fabric is produced on flat bed knitting machine with needles having hooks on both ends. To support such needles two beds are required in the same plane with trace opposite to each other to allow sliding of needle. Each hook is used alternately to produce face and back loops in alternate courses. The needles do not have butt for movement but *jacks* helps to works as butt using hook opposite to that of knitting hook.

A notch underside of the front end of the slider just fits over the hook of the needle. Butt of jacks work in the track.

The special features of a purl machine are:

i. needles used has two hooks, one on each end, and is without butt. They operate with sliders.
ii. These sliders indirectly performs the knitting action of needles by either seizing or releasing the needles.

Needle of a purl machine

iii. The needle bars are placed horizontally with tricks opposite to each other.

Knitting cycle of purl fabric

In knitting cycle of a *Flat bed purl knitting machine,* to form purl stitch, the needle is required to slide from one bed to another after knitting each course.

i. the double headed latch needle is in its rest position in the front bed and held by front bed slider.

ii. The delivery slider (d) advances with the needle so that the nose of the slider which is extended into a latch guard, penetrates the profiled recess of the delivery cam. The outer hook of the needles comes in contact underneath the head of receiving slider (R), pivot it out of the cylinder momentarily.

iii. The receiving slider engages the needle hook under the influence of coil spring board (SB) which ensures that the slider's head are depressed into contact with the needle hooks.

iv. As slider (D) revolves with the cylinder, it passes along the wall of the deviding cam (DC) which increases in thickness, so that the slider is pivoted outward and disengaged from the needle hook. Slider D then returns to its cylinder while R retire into its cylinder taking the needle with it ready for the next knitting feed.

v. The yarn carrier then feeds yarn in the hook of the opened front end of the double headed latch needle. The needle is retracted to rear bed by stitch cam to knit plain faced loop fabric.

In figure, a jack or slider used on a *circular purl knitting machine* is shown. In this case the sliders have butts, a knitting butt (A) near to its tail. Each butt is controlled by its own cam track. The needle base are in two cylinders superimposed one above the other.

4. Quality control & Production of knitted fabric

4.1 Faults in knitting

Faults in weft knitting production can be caused in various ways and quite a few of them cannot be related to just one cause. These faults can be due to one or more of the reasons:

1. Material
2. Man
3. Method
4. Machine

Most of the faults related to Method and Machine can be attributed to have been occurring due to Man. The source of faults could be

- Faults in yarn and the yarn package
- Yarn feeding and yarn feed regulator
- Machine setting and pattern defects
- Machine maintenance
- Climatic conditions in the knitting plant

The faults can appear coursewise (horizontally), or walewise (vertically). Horizontal lines can appear due to material (uneven yarn, mixed yarns, uneven twist in yarn, poor winding from cones), machine (uneven stitch length, uneven take-down tension, uneven stitch cam). Vertical lines appear due to machine i.e. needles (bent needle, bent hooks, chipped latches, butts or broken spoons, worn needles, wrong needle, i.e. needle size not appropriate with the cut of the machine), trick slots (dirt in trick slots, defective or worn-out tricks walls, needles too ;oose or tight in tricks), sinkers (stiff, sinkers ride high because of dirt).

Faults are very difficult in nature and appearance and are often superimposed. Faults due to

4.1.1 Material

Material used in knitting is yarn. It is used in cone or cheese form. Yarn faults shows coursewise or horizontal appearance in knitted fabric. It is called as Barre Effect (Horizontal bars of real or apparent variation in due depth extending across the full width of the fabric. It may be narrow of wide bands. or variable in thickness).

Fault category (YARN FAULTS)	Appearance, cause and remedies
Unevenness	will appear as cloudy or wavy appearance in fabric.
Yarn count variation	Will appear as dark and light strips in fabric. Can cause holes, and bad appearance in fabric.
Spun-in (colour fiber)	Causes to appear as different colour fibre in the fabric.
Foreign matter, lint, bad knots and slubs	Will cause holes and cutting in fabric.
Short thick places, Short thin place	Will show as small strips. Thin places will also increase breakage during knitting, holes and cutting. Thick places can affect needle.

Long thin place, Long thick places	Will show on fabric as cloudy or wavy appearance. Long thin place will increase breakage during knitting, holes and cutting. Think places can cause needle damage.
Twist	High twist yarn will cause snarls during knitting. It may also damage needles. This defect will increase curling of fabric causing problems in cutting and laying up of fabric.
Friction	Friction is an important factor in knitting. The yarn is less twisted and soft. It passes through many guides at high speed leading to friction. The friction between yarn and metal should not exceed 0.17 otherwise it will lead to fly generation, spoiling of yarn leading to spoiled appearance of fabric, fly generation during knitting. So, yarn should be properly lubricated. .
Cotton mixing	If not properly mixed, the cotton from different filed has different dye uptake. It will lead to alternate bands of light and dark shades appearing coursewise.
Damaged or soiled cones	Will cause breakages during knitting. A soiled cone will also show the stain marks in fabrics.
Periodic variation	Appears in the yarn due to some defect of gear or roller in Spinning. It will show as patchy fabric.
Holes and cutting	weak yarn, yarns with bad knots and slubs, lint in yarn guide or eye-pots, stitch drawn too tight, stiff latch, unsuitable yarns number etc.
Bareness	Horizontal bars of real or apparent variation in due depth extending across the full width of the fabric May be narrow of wide bands. Or variable in thickness. May occur on a set or a variable frequency. Caused in the case of bulked yarns by a variation in bulk

4.1.2 Man

Oil spots or oil marks	Oily spots on fabric. Oil mark spread across the fabric at the end of the piece and possible spreading through other layers.	Mainly due to oil dripping onto the fabric as a result of over oiling of the knitting machine and a failure to remove the surplus oil, or malfunction of oiler. Spiling the oil on the fabric during lubricating. Failure on the part of the knitter, when doffing of the machine, to remove surplus oil from the end of the bar prior to removing the bar from the piece. Oil is spread across the inside layers or layers and may migrate to other layers.

Bareness	Horizontal bars of real or apparent variation in due depth extending across the full width of the fabric May be narrow of wide bands. Or variable in thickness. May occur on a set or a variable frequency	Improper setting of stitch cam. May be caused in the case of bulked yarns by a variation in bulk
Oil line	Vertical oily lines running down on or more wales. Intense at the one end and fading away.	Excessive oil on the needle. Improper cleaning of machine.
Dirty fabric		Keeping the fabric on the dirty floor. House keeping not proper.
Soiled yarn	An obvious dirty streak or streaks along a course or courses, or indeterminate length and coverage	Contamination of cones due to miss-handling with soiled hand.
Moiré marks	Water marks similar in appearance to ant forgery engravings on paper money	This fairly uncommon fault occurs when fabric processing a pronounced warp ways or weft ways rib structure is held under pressure with itself while standing or during finishing. Produces a visible wave form between embossed and non embossed sections of the fabric
Count mix up	Horizontal lines visible in fabric.	Either by wrong sticker of count on cone. Or while hadling, adding of a different count cone.

4.1.3 Methodology

Wrong count selection	Spoiling of the appearance of fabric. The fabric may appear too tight or loosely knitted.	Wrong (course or fine) count is selected for knitting a fabric. The fabric may appear too tight or loose
Different coloured fly knitted	Fluff of dyed yarn visible in the fabric (esp in grey fabric)	Different coloured yarn knitted in adjacent machines. Low house keeping. The fluff of one may accumulate in the other yarn.

4.1.4 Machine

The faults may come may appear in fabric horizontally or vertically. Horizontal faults appear due to cam or take down mechanism. Vertical faults appear due to needles.

Bareness	Horizontal bars of real or apparent variation in due depth extending across the full width	Due to variation in stitch cams used, unequal setting of knock-over on dial and cylinder at

	of the fabric May be narrow of wide bands. Or variable in thickness. May occur on a set or a variable frequency	different. Feeders. Slippage or variation in take down mechanism.
Ladder defect	Appearance of distorted vertical loops.	Broken hook, broken butt.
Bow defect	The fabric appears to be bent towards one side.	Variation in take down tension.
Missing loops		Gaiting in rib or interlock. Timing of needles and sinker.
Drop stitches	Ladder of length dependent upon the vigilance of the knitter	slack yarn tension, stiff latches, take down mechanism too loose, latch not opened, needle timing set wrong, needle slots clogged with dirt, machine running too fast, positive feed slippage, wrong stitch setting
Distorted stitches		bad or bent needles, incorrect positive setting, uneven yarn tension, bent trick walls, needle timing wrong, improper stitch cam setting
Press-off	when a end of yarn breaks out the needle will knock over its previous loop without forming a new stitch. This is called an end out. If this end out occurs in succession on a number of needles, it is called a drop out	faulty stop motion, plugged yarn guide with lint, bad yarn, machines running fast, bad knots and slubs
Loop accumulation	Bunch of loops appear	

4.2 Quality requirements of knitted yarn

1. *Yarn evenness*: Better knitting performance and better fabric appearance can be achieved with yarns having better evenness. Yarn containing large knots and slubs will result in excessive needle breakage, causing drop stitches and holes.
2. *Twist*: Soft twisted yarn give soft handle and bulkiness to the fabric. High twisted yarn make fabric rough and these yarns get snarled during knitting causing needle damage and fabric faults. Generally, the twist factor in hosiery yarn ranges from 3.0 to3.4 luster and hand of fabric are affected by amount of twist.
3. *Count variation*: Higher count variation in yarn show thick and thin places in the knitted fabric.
4. *Neps and foreign matters*: Selection of fibers and processing in blow room, carding and combing departments should be given careful consideration for the better appearance of the fabric. The

foreign matters present in the yarn such as jute, hair, coloured yarn, rubber, plastic pieces, cloth pieces, polypropylene etc should be removed in blow room and winding processes.

5. *Thick and thin places*: Higher number of thick and thin places and the undrafted places affect the knitted fabric appearance. Thick places due to poor opening and carding and undrafted places may damage the needles and thus result in fabric defects as well as increase in stores expenditure.
6. *Elasticity and elongation*: Higher tenacity of yarn does not always give good knitting quality. A good hosiery yarn should possess enough elongation to withstand tension during knitting and knitting action by the needles. The elasticity of yarn varies with humidity and temperature, spinning technique, single or doubled yarn with high (or) low twist.
7. *Resistance to friction*: During knitting, the yarn passes through several paths, and this will increase the friction unless the yarn and the paths are polished (or) smooth. Therefore the yarn to metal friction should be reduced to a considerable extent, otherwise yarn breakages, will occur and hence fabric damage.
   The low coefficient friction value of less than 0.2 can be achieved by waxing the yarn either by passing through wax in winding or by wax emulsion method.
8. *Moisture content in yarn*: A very dry yarn impairs extension characteristics and also leads to fluff build up. On the other hand the coefficient of friction of the yarn increases with increasing moisture content. Moisture content in the yarn should be 10 to 14%.
9. *Winding package buildup*: knit yarn packages are generally offered with a iconicity of 5* 57' instead of 9*15'. A high friction yarn produces a harder package due to higher winding tension and this will knit a tighter structure. The package hardness can be assumed at around 0.4 kg/dm2 for the practical purposes. The winding faults such as tight cones, soft cones, uneven winding, loose ends, double ends, thick places, thick knots, etc should be avoided.
10. *Knots and splices*: Generally the knot size will be about 4 to 5 times the yarn diameter, but in the spliced yarn, the diameter at the spliced point will not exceed more than 1.5 to 2 times the yarn diameter. Therefore, for knitting spliced yarn is an advantages than knot yarn. Generally, combed yarns offer a clean appearance, better lusture than carded yarns. Combed yarns are used in quality knit wear while carded are used for cheap varieties. Some knitters even use mercerized (or) gassed and mercerized yarn to make superior quality outerwear fabrics for export markets.

4.3 Control of fabric quality

A technician in charge of the quality control system should first prepare specification sheets of the fabrics to be knitted.

1. *Yarn specifications include*: supplier name, count, twist, colour On this sheet the technician should make a mention of 'tolerances' allowed for each specification.
2. *Knitting machine setting sheet* should give information on diameter, gauge, knock over time, dial height, take down tension, needle specification, machine speed, yarn speed, course length, yarn tension, and cam setting.
3. *Fabric details* should include CPI of machine, WPI of machine, stitch density, weight per square meter, width of fabric and fault rate standard.
4. *Finishing details* should give the type of finish required.
5. *Final examination specification* should include weight per linear meter, width, standard piece weight, length, percent finish loss, fault allowance.
6. *Inspection of the fabric* will include check for uneven fabric, for patterning of coloured fabrics, for ladder running, for oil staining, for proper take down tension for barrenness.

4.4 Robbing back

As the needle moves down, it needs more yarn to pull down. This yarn has to be pulled through the yarn fed to the other needles and hence a very high tension has to be developed to draw the yarn in then direction. Yarn is, therefore withdrawn from the loops already knitted, as it is easier to do so. A certain amount of yarn is thus 'robbed' back from the loops already knitted. The actual stitch length is therefore reduced to less than the theoretical stitch length, even at the minimum tension of say 2g. The minimum length robbed back is about 30 per cent of the theoretical stitch length.

At the much higher tension, this robbing back can occur from the yarn fed to the preceding needless. If one loop is to knock over successfully some of this robbing must occur, otherwise it will never be able to slide over the hook and latch. However if a very high tension develops, the yarn breaks or becomes distorted. To avoid this, the stitch should be knitted at low tension depending upon the strength and elongation of the yarn.

4.5 Fabric tightness or compactness

Like warp cover, weft cover and fabric cover in weaving, it is also calculated in knitted fabrics. Here, it is also called as the tightness factor. It helps us to know how much compact the knitted fabric is. It refers to the area occupied by loop. It is a factor of ratio between the yarn diameter and loop length. State of relaxation does not affect the ratio. It is possible that two fabrics of same compactness, one with small loop length and fine yarn count and other with a large loop length and heavy yarn count.

The compactness influences the fabric properties of durability, drape ability, handle, strength, abrasion resistance, dimensional stability, and in cool, felting behavior.

Tightness factor = ratio of area covered by the yarn in one loop to the area occupied by loop total area covered by yarn= $s \times l \times d$ & $s = k s / L$

L= loop length (in mm)

D= yarn diameter (in mm)

The area covered by 1 cm2 of fabric= $$\frac{k s \times l \times d}{L^2 X 100}$$

$$= \frac{Ks \times d}{100\ L}$$

For same type and yarn in similar state of relaxation a simplifies formula,

TF, $K = \frac{\sqrt{TEX}}{L}$ in S.I. units

$$S = \frac{K s}{L\ 2}$$

$$\frac{CPI}{WPI} = \frac{kc}{kw} = R$$

Where R = Loop shade factor

For plain fabrics

The fabric is wetted for 24 hours in water at 40ºC, briefly hydro extracted to remove excess water and then dried for 1 hr at 70ºC.

	Dry relaxed	Wet relaxed	Fully relaxed
K s	19.0	21.6	23.1
K C	5.0	5.3	5.5
K W	3.8	4.1	4.2
R	1.3	1.3	1.3

Factors affecting fabric dimension are

i. Loop length or stitch length
ii. Affects size variation.
iii. Use positive feed under low tension instead of allowing latch needle or loop forming

4.6 Knitting calculations for weft-knits

In any manufacturing process, the calculations regarding production, efficiency and material requirements are of primary importance. The organization of machinery requirements, raw material requirements and the costing of the finished products, so as to determine the competitive selling price, will mainly depend upon the correct calculations. Knitting manufacturing is no exception to this rule. Methods of calculating production and efficiency of machines, used for weft knitting, are given as illustrations. Though the metric system of weights and measurements is used in India, the textile industry in general and the knitting industry in particular, has not yet fully adopted this system. The calculations are usually done in 'foot-pound' system at the shop floor and only the last figures are converted into metric system from the British system of weights and measurements. In a majority of examples solved in this chapter, therefore, the British system of weights and measurements is used with a few examples also solved in metric units and in direct system of yarn numbering.
Before dealing with the examples, a definition of gauge of knitting machines is given here:

4.6.1 Machine gauge

Circular weft knitting machines: Gauge is defined as the number of tricks per circumferential inch. It is also known as the 'cut' of the machine. It two sets of needles are used as in rib or interlock knitting machines, the second set of needles is not taken into consideration in determining, the gauge. Sometimes, however in giving the gauge of a circular rib or interlock machines the gauge number is repeated e.g. 18x18 rib, 22x22 interlock etc.

4.6.2 Relation between yarn number bad machine gauge

It is not possible to knit a large range of yarn counts on machine of one gauge. Owing to the lack of standardization of the proportion of thickness of the needles and sinker to the total needle spacing, a relation between the of the machine and yarns used on them can be approximately dependable. Even yarns are not standardized for strength, diameter, twist and bending strain. The type of stitches used also plays its part. A machine cannot be expected to knit up as coarse a count of yarn for tuck stitches as a plain stitch. The correct gauge of a given type of machine for knitting up a given yarn can only be found by practice. However, some formulae based on experimental results are given here as a rough guide.

$$\text{Worsted yarn number} = \frac{(\text{needles per inch})^2}{\text{Constant}}$$

The constants for different stitches are: plain jersey 14, 1x1 Rib 6, 2x2 Rib 8, Interlock 10. By substituting the proper constant, the estimated gauge can be calculated. If cotton yarns are used for rib and interlock structures then a constant 8.4 can be taken (alternatively, cotton count can be converted into worsted yarn number and the above formula and constant can be used)

For flat 1x1 rib machine

$$\text{Worsted yarn number} = \frac{(\text{Gauge})^2}{9}$$

For French circular sinker wheel machine

$$\text{Worsted yarn number} = \frac{(\text{Gauge})^2 *}{28}$$

$$\text{Or } \frac{(\text{Gauge})^2 **}{47}$$

4.6.3 Calculations of weft knitting machine and fabrics

The linear production of a circular weft-knitting machine depends on

i. number of feeders
ii. Number of revolutions per minute
iii. Efficiency
iv. Number of courses per inch(C.P.I.)
v. Stitch length
vi. Stitch length in inches
vii. Number of needles
viii. Yarn number in indirect system(count)

Then the following formulae can be used to find various quantities:

1. Yards of knitted fabric per hour

$$= \frac{\text{no. of feeders x no. of r.p.m x efficiency x 60}}{\text{No. of C.P.I X 36 X 100}}$$

2. Production per hour in lbs

$$= \frac{\text{no. of feeders x no. of R.P.M. X efficiency X stitch length (in)X no. of needles x 60}}{\text{Count X yards per hank X 36 X 100}}$$

$$= \frac{\text{no. of feeders x no. of R.P.M. X efficiency X stitch length (in)X no. of needles}}{\text{Count X 50400}}$$ FOR COTTON (840 yards = 1 hank)

$$\text{Or } \frac{\text{no. of feeders x no. of R.P.M. X efficiency X stitch length (in)X no. of needles}}{\text{Count X 33600}}$$ FOR worsted (560 yards=1 hank)

Example1. A circular weft-knitting machine having 20 feeders, running at a speed of 25 rpm, is knitting fabric with stitch length equal to 0.15 inch with 756 needles in the machine. The efficiency of machine is 84% and the count yarn knitted is 18s. The fabric is knitted with 24 courses per inch. Calculate the production in yards and pounds per hour.

1. Yards of knitted fabric per hour

$$= \frac{20 \text{ X } 25 \text{X} 84}{60 \text{ X } 24} = 29 \text{ YARDS}$$

2. Production per hour in lbs

$$= \frac{20 \text{ X } 25 \text{ X } 84 \text{ X } 0.15 \text{ X } 756}{18 \text{ X } 50400}$$

$$= 5.25 \text{ Lbs.}$$

Weight per linear yard

Instead of determining the stitch length, sometimes stitches per foot are determined. This is obtained by placing two marks on the yarn at a distance of one foot, as it approaches the needles and counting the number of needles between the marks as the yarn is knitted into cloth. This should be repeated several times to assure accuracy. To calculate the weight per linear yard by this method, the following formula can be used.

Weight per linear yard in lb

$$= \frac{\text{total needles X courses per inch X 36}}{\text{Stitches per foot X 3 X 840 X cotton count}}$$

$$= \frac{\text{total needles X CPI}}{\text{St/ft X cc X 70}}$$

Example2. A Single jersey fabric is made on a machine with 2040 needles with 28 courses per inch from 17s cotton count yarn and 80 stitches per foot. Calculate the weight per linear yard.

Weight per linear yard

$$= \frac{2040 \text{ X } 28}{80\text{X } 70\text{X } 17} = 0.6 \text{ lbs}$$

Example3. If four samples of four square inch each, weigh 32 grains (total weight) and the jersey fabric is 16- inch tubing, determine the weight per linear yard.

Weight per linear yard

$$= \frac{9 \text{ X } 2 \text{ X } 16 \text{ X } 2}{1750}$$

$$= 0.33 \text{ lbs}$$

Calculation of yarn diameter assuming a specific volume of 1.1

Indirect system

Yarn dia. $d = \frac{1}{K\sqrt{N}}$ inch

Direct system

yarn dia. $d = \frac{\sqrt{N}}{K}$ inch

System	Value of K	System	Value of K
Cotton count	28	Denier	2036
Worsted count	22.8	Tex	678.6
Yorkshire skein woolen	15.4		

Example4. A 490- needle machine is knitting 25s cotton count yarn. What will be the theoretical width of the fabric?

Yarn diameter $= \frac{1}{28\sqrt{N}}$

$= \frac{1}{28\sqrt{25}}$

$= \frac{1}{140}$ inch

Width of one wale = 4 X d = 4 $\frac{X\ 1}{140}$ inch

Width of fabric

= needles X wale spacing

= 49 X $\frac{4}{140}$ = 14 inches

Example5. What difference will be produced in the width of the fabric by changing from 36s c.c. to 25s c.c. it the width of the fabric is 20 inches with 36s count?

$\frac{\text{Width of old fabric}}{\text{Width of new fabric}} = \frac{\sqrt{\text{new yarn number}}}{\sqrt{\text{old yarn number}}}$

$\frac{20}{X} = \frac{\sqrt{25}}{\sqrt{36}}$

: x= 20 X 6/5 = 24
: width of the new fabric = 24 inch.

Example6. What number of needles will be requires in a cylinder to produce a fabric of 12 inch wide using 16s yarn?

Yarn diameter = $\frac{1}{28 \times \sqrt{16}}$ inch
= 1÷112

Width of one wale= 4 X 1÷112 inches
No. of needles = $\frac{\text{width of fabric}}{\text{Wale spacing}}$
= 12 X 112÷4 = 336
Total no. of needles in the cylinder =2 X 336 = 672

5. HOSIERY

This term specifically refers to knit coverings for the feet and legs but can be generally applied to all types of knitted goods and fabric.

They are mostly knitted on small diameter circular knitting machines. The machines have a master control. The automatically initiates operation and also changes stitch length necessary to produce garment length knitting cycle. Hosiery is available in different foot sizes. The commonly used hosiery articles are as below. They are categorized as per length articles.

Hose: the covering having a length above the knees.

Three-quarter hose: The covering of knitted fabric of knee length (approx twice the foot length).

Half hose: The knitted fabric covering of feet ranging between 7 inch and 9 inch and 11 inch and 15 inch. They are up to nearly half the knee length.

5.1 Machine used

1. Single cylinder; ladies, seam less hose, tights
2. Cylinder and dial.
3. Double cylinder: man half hose

The hand powered socks knitting machine was patented by Henry Grisuuold in 1870. It has a small diameter latch needle cylinder with the single rotating cam and feeder system. This could be oscillated to produce heel and toe pouches. An attachable dial was available to prepare rib top of socks.

5.2 Production of hose

The hose is produced from top rib to the down heel that is later on stitched. To produce top rib the dial is attached and sometimes an extra elastomeric yarn is attached for producing better grip. The yarn from dial is then transferred to the normal knitting till the heel portion is to be knitted.

In production of standard heel and top, half of the courses will be in oscillating knitting; and may require 60% of the machine operating time. the operation although is automatic, is time consuming and expensive.

Producing heel, the oscillation of feeder takes place on half of the needle knitting pouches. The remaining needles (nearly half), are raised into a high inactive cam track. By introducing a cam.

During *narrowing*, the leading needle in each direction of oscillation is lifted up to join the other needles in the in active track by the action of one or two side pickers that are alternately in action, according to the direction of oscillation. The picker operates throughout the pouch formation process. When widening takes place down pickers is introduced. This down picker lowers two needles at a time and putting them into action.

To produce *standard heel (or toe)*, half of the needle are raised and rest half the needles knit. The narrowing down of the heel section takes place by getting one needle out of action from each side, with each oscillation. Narrowing occurs till one third of the needles remain in action. The needles lifted out of action has yarn automatically wrapped over it in form of a tuck stitch. This makes heel joint stronger. Widening then takes place with needle brought down from each side with each oscillation until all the heel section needles are brought back into action (i.e. half the total needles).similarly, a toe pouch can be knitted.

If the same set of needles, as used earlier, are repeated then the seam will be top (preferred in socks). If the use of other half set of needles is made then the seam will be underneath (in hose).

5.3 Modification in heel or toe

To the basic pouch, particularly on hose, modifications are done to improve fit and appearance.

i. *Y- heel*: Narrowing down takes place to 1/3 of the needles. Extra fabric is then knitted by widening for 12 courses, and again narrowing it to 1/3 of needles of next 12 courses. The normal widening is then carried out.

ii. *Gusset toe*: A toe knitted in reverse, after 1/3 of the needles left, a group of needle is collectively introduced. Then single needle narrowing occurs for the next 12 courses. Then the rest of the needles required to be lifted (to make 1/3) are taken out of action. The normal pouch widening then take place to half of the needle.

iii. *Scotch heel*: they are fully fashioned seam less hose on flat knitting machine made as tubular fabric. Narrowing of fabric is carried out for a few courses (normally 9 to 10). Then approximately $1/3^{rd}$ of the loops from each side of the needles are taken out and held on two wires. Knitting is continued on the middle portion and on each course one loop is transferred to each wire from the bed producing narrowing of fabric with twice as many courses as wale in the width. The edge which was taken out is then resumed on needles and turn in the heel is made. Normal knitting is resumed.

6. WARP KNITTING

Warp knitting is the method of making a fabric in which the loops made from each warp thread are formed along the length of the fabric. It is the best method of fabric production using mainly continuous filament yarns.

6.1 Definitions in warp knitting

The lapping movement is composed of two separately derived movements- a swinging movement (A-A) and a shogging movement (B-B). These are at right angle to each other. The *swinging* movement is the arc from the front of the machine to the hook. There is also a return swing motion. There is then the movement parallel to the needles bars and is called as the *shogging* movement. This movement produces over lap and under lap.

The warps knitted loop is made of two parts. The first one is the loop itself, which is formed by the yarn being wrapped around the needle (swinging) and drawn through the previous loop. This part of the loop is called an *overlap*. It is the lateral movement of the guide bars on the beard or hook side of the needle. Overlap movement normally occurs over only one needle space. A double or more needle space cause severe strain over warp thread and the needle. The second part is the length of yarn connecting the loops, which called an *underlap*. Under lap can be defined as the lateral movement of the guide bar made on the side of the needle remote from the beard/hook. This can take place over any number of needles depending upon pattern requirements. Longer under lap produces heavier, thicker and denser fabric.

6.2 Basic lapping variations

To form a solid fabric with a single guide bar it is necessary to connect individual wales at every course by causing each warp thread to knit on a different needle at each successive course. There are two ways of achieving this result. If the segments of threads at the base before connecting the other stitch is crossed while the threads do not cross at the base of each loop. The former is called a *closed loop* and the later an *open loop*.

1. *Open lap* is formed when the overlap and the next under lap are made in the same direction.
2. *Closed lap* is formed when the overlap and the following under lap are in opposite directions. The closed lap is more popular which is used in the construction of majority of warp knitted fabrics. These are heavier, more compact, opaque and less extensible as compared to open lap.
3. *Open laps* are formed when only overlaps, and no underlaps are there.
4. *Laying-in* are formed only with underlaps and no overlaps are used.
5. *Miss- lapping* when there is neither underlap nor overlap.

6.2 Classification of Warp knitting

The two major classes of warp knitting are *Tricot* and *Raschel*. In the past, it was usual to distinguish between these two classes by the needle used in each type. Tricot machines were equipped with bearded needles in conjunction with a presser bar, while Raschel used latch needles with a latch wire. In modern machines, however compound needle replaced the bearded in tricot and penetrated into the Raschel also. Therefore the classification of machines based on needle type is not appropriate.

An *accurate classification* can be made by the type and role of sinkers in the machine. Sinker of tricot machines combine the functions of holding-down, knowing over and supporting the fabric, whereas Raschel sinkers only perform the function of holding down the loops when needles rise.

6.2.1 Tricot knitting

A warp knitting system generally using bearded (sometimes compound) needles mounted vertically in which the fabric is supported and controlled by sinkers.

1. Tricot machines were equipped with bearded needles in conjunction with a presser bar.
2. Sinker of tricot machines combine the functions of holding-down, knowing over and supporting the fabric.
3. The fabric is taken away from the knitting zone at approximately 90º to the needle (nearly horizontal).
4. This is most common type of warp knitting machine.
5. In this machine the needles are mounted vertically in tricks in a horizontal mental bar known as needle bar. The length of this bar determines the knitting width.
6. The gauge of this machine is given by the number of needles per inch (18 to 40 NPI).
7. Modern Tricot machines are manufactured in width up to 260 inches and producing fabrics at high rates up to 3500 courses per minute.
8. They are used for the production of apparel and household fabrics particularly using continuous filament yarns.

Guides of tricot machines are cast in one inch units and hang vertically from the guide bar. Each guide bar has one guide per needle and they are arranged so that they swing between the needles during the knitting cycles. All the guides containing the yarns from a single warp are connected to a guide bar so that all of them move uniformly. The guides swing between and around the needles in order to warp the yarn around them to form a new loop. They also shag sideways to connect the wale into a fabric. These machines are fitted with 2 to 5 guide bars although 2 is the most common. The sinkers are usually cast in units of one inch long and screwed into the sinker bar. The sinkers of tricot machines combine the function of holding down, knocking over and supporting the fabric loops. These machines are usually equipped with a presser which is used to close the beard of the needle during loop formation. Its main knitting elements are shown in figure.

6.2.2 Raschel knitting

It is system of warp knitting having vertically mounted latch or compound needles.

1. Raschel knitting machine used latch needles with a latch wire.
2. Sinkers only perform the function of holding down the loop when needles are rising.
3. The fabric is supported on trick plates and is withdrawn from the knitting zone in a down wards direction at an angle of about 150º.
4. this is the second type of warp knitting machine.
5. The main knitting element of machine i.e. compound needles are set(as in tricot machines) into tricks cut into the needle bar. The latch needles are usually cast in units of one inch long and fitted vertically into a needle bar across the width of the machine.
6. Gauge is expressed in needles per two inches. These machines are constructed in different gauges, ranging from 12 to 64 (6 to 32 NPI).
7. Width of the machine is usually 75 to 230 inches. Modern raschel machines can run up to a speed of 2500 courses per minutes.
8. These machines are capable of knitting both staple and continuous filament yarns for furnishing, technical and jacquard fabrics. Although lace was original product, these machines are manufactured today for the production of a variety of fabrics for different end uses.

Guides of Raschel machines are steel blades with a hole through which the warp thread passes and they are also cast in one inch units and mounted on guide bars. These machines usually equipped with a large number of guide bars (up to 78) than tricot machines. Like latch needles, the sinkers of

Raschel machines are cast in units of on inch long and fitted between the needles. Their purpose is to hold the fabric down as the needle rises during the knitting action. The loop formation in Raschel machine takes place on the upper edge of the trick plate which is a vertical metal plate across the width of the machine. This can be considered as a needle bed because the needles are placed in tricks cut into it. Latch needle Raschel machines are equipped with a latch guard which is a steel wire stretched across the width and keeps the latches down during the rise of needles. These machines are available with jacquard mechanism and weft insertion magazines.

6.4 Warp knitted structure

6.4.1 Atlas

It is formed when a warp thread moves in one direction for a number of consecutive courses, and for equal number of consecutive picks in opposite direction. The lapping is called Atlas. These stitches can be both open or close lap.

1-0/1-2/2-3/3-4/4-5/4-3/3-2/2-1 0-1/2-1/3-2/4-3/5-4/3-4/2-3/1-2

Open Atlas

Closed Atlas

BGB 1-0/1-2/2-3/3-4/3-2/2-1/
FGB 3-4/3-2/2-1/1-0/1-2/2-3/

Birds eye Atlas

Double Atlas

6.4.2 Queen's cord

The general rule is that longer underlaps are made BGB and shorter lappings are made by FGF by knitting on the same needles continuously.

BGB 1-0/2-3 FGB 0-1/1-0

6.4.3 Lock knit

BGB moves in opposite direction of FGB.

BGB 1-2/1-0/ FGB 1-0/2-3/

Lock knit

BGB 1-0/2-3/ FGB 1-2/1-0/

Reverse Lock Knit