Analysis of Overall Equipment Efficiency (OEE) of knitting machine varying different operating parameters.

by

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A project work submitted in partial fulfillment of the requirements for the degree of Master of Engineering in Advanced Engineering Management.

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CERTIFICATE OF APPROVAL

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Mohammad Hosain Reza.

Dedicated to my parents.

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ABSTRACT

Overall Equipment Efficiency (OEE) is a tool of Total Productive Maintenance (TPM). Total Productive Maintenance is a plant wide maintenance program, which involves a newly defined concept for maintaining plants and equipment for its entire life span. The goal of TPM is to maximize Overall Equipment Efficiency by increasing production while at the same time, increasing employee morale and job satisfaction. It evaluates efficiency not only in respect of productivity. It takes into account all the basic three components of production: availability, performance and quality to calculate the OEE. All the three components must have higher values, to obtain a higher value of OEE,

Garments and Textile industries have already proven its place in the economy of Bangladesh. Most of the industries are private owned and working separately from each other. Though a tremendous success this sector is running with a lot of problem especially during balancing their productivity and working conditions.

Like all other industries, this sector also looking for higher profit. It is a simple calculation that if we increase speed with in a limit the productivity of the machine increases. But in this research work it has been analyzed that higher figure for OEE cannot be always considered for a wise decision.

This thesis work analyses the OEE of knitting machine to obtain a better environment of knitting section.

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Chapter 1

Introduction

1.1 Introduction

The RMG business started in Bangladesh in the 70's but it was then merely a casual effort. Afterwards it is a story of sustained success for the Bangladesh RMG sector. The knit-wear sector has grown over the years in geometric progression and has become the prime driving force of Bangladesh's export earnings. Bangladesh is the second largest Garments Exporter country in the world. It is the main export item of Bangladesh. Among them about 50% of the garments are knit items which are produced completely in Bangladesh from yarn to garments. There are many knit-dyeing factories in Bangladesh which supplies dyed and finished fabric to the Garments industries. But unfortunately there have been a very little work of research and literature done in this sector [1]. In today's industrial scenario huge losses/wastage occur in the manufacturing shop floor. This waste is due to operators, maintenance personals, process, tooling problems and non-availability of components in time etc. Other forms of waste include idle machines, idle manpower, breakdown of machines, rejected parts, etc, are all examples of waste. The quality related waste are of significant importance as they matter the company in terms of time, material and the hard earned reputation of the company.

In this research one of the TPM tool called Overall Equipment Efficiency (OEE) will be used to analyze the performance of the knitting process [2, 3]. OEE determines the equipment performance of the knitting machine in terms of availability of the machine, performance rate and quality product rate which further incorporate losses related to equipment failure, set-up and adjustment, Cutting Blade change, Start-up, Minor stoppage & idling, Speed and defect rate [4, 5].

1.2 Objectives of this study

The specific objectives of this study are:

a) Identify the losses related to machine speed, type of yarn and no. of feeder of a knitting machine.
b) Evaluation of the Overall Equipment Efficiency (OEE) of the knitting machines.

c) Obtain optimum condition by analyzing Overall Equipment Efficiency.

The major possible outcome of this study is:

Find out the optimum condition for knitting by analyzing the OEE.

1.3 Importance of this study

Bangladesh is a densely populated country. For a country like us, Garments and Textiles industries are very suitable. We have sufficient labor which is essential for this industry. Now, Garments and Textile industry is the thrust sector for the economy of Bangladesh. But unfortunately a limited number of research works has been done for this sector. The industries which are mostly private companies doing their work based on their experience. During installation of a new industry the foreign machine suppliers provide the technical information. Based on that, the industries train-up their manpower. But they have a very little time to judge the information.

Today's challenging world demands minimum loss and waste from industries. Moreover it has to ensure better quantity and quality. Calculating quantity and waste is not an easy work as it seems like. At this point one has to focus on optimum quantity and waste. In other words we have to search for optimum speed and time for each work to be done.

One has to think multi-dimensionally to obtain the optimum speed. Sometimes we have to allow less speed and efficiency if we want better output. Again it is related to working conditions.

In this study it has been tried to find out the optimum speed and number of feeders for a knitting machine focusing on the above mentioned points. Finally a comparative study has been done on waxed and unwaxed yarn.

The author has tried to open a door focusing on work study and knitting dynamics in this project work.

This will be very much helpful for knitting sector which has a limited number of researches to work with.

Chapter 2

Overall Equipment Efficiency: Literature Review

2.1 Introduction

Total Productive Maintenance (TPM) can be considered as the medical science of machines. TPM is a maintenance program which involves a newly defined concept for maintaining plants and equipment. The goal of the TPM program is to increase production while, at the same time, increasing employee morale and job satisfaction [4].

TPM brings maintenance into focus as a necessary and vitally important part of the business. It is no longer regarded as a non-profit activity. Down time for maintenance is scheduled as a part of the manufacturing day and, in some cases, as an integral part of the manufacturing process. The goal is to hold emergency and unscheduled maintenance to a minimum.

2.2 History of TPM

Total Productive Maintenance is an innovative Japanese concept, which has started to the early 1950s when preventive maintenance was introduced in Japan. The concept of preventive maintenance originated in the USA. Preventive maintenance is the concept of daily maintenance designed to maintain equipment in good condition and prevent failure through the prevention of deterioration and periodic inspections.

Nippondenso was the first company to introduce plant-wide preventive maintenance in 1960. Nippondenso operators used machines to produce products and the maintenance group maintained the machines. With the introduction of more and more factory automation, maintenance became a problem because more maintenance personnel were required. Management decided that the production operators could perform the routine maintenance on their equipment (Autonomous Maintenance, one of the features of TPM). The maintenance group could then focus on essential maintenance projects.

Thus, Nippondenso, which already practiced preventive maintenance, also added Autonomous Maintenance performed by production operators. The maintenance group began identifying modifications to improve overall equipment reliability. The modifications were made or incorporated in new equipment. This led to Maintenance Prevention. Preventive maintenance along with Maintenance Prevention and Maintainability Improvement gave birth to Productive Maintenance. The goal of productive maintenance was to maximize plant and equipment effectiveness to achieve optimum life cycle cost of production equipment. By then Nippondenso had made quality circles, involving the employees' participation in implementing Productive Maintenance. Based on these developments Nippondenso was awarded by the Japanese Institute of Plant Engineers (JIPE) the distinguished plant prize for developing and implementing TPM. Nippondenso of the Toyota group became the first company to obtain the TPM certification [4].

2.3 Features of TPM

Motives of TPM:

Adoption of life cycle approach for improving the overall performance of production equipment and Improving productivity by highly motivated workers which is achieved by job enlargement.

The use of voluntary small group activities for identifying the cause of failure, possible plant and equipment modifications [6].

Uniqueness of TPM:

The major difference between TPM and other concepts is that the operators are also made to involve in the maintenance process. The concept of "I (Production operators) Operate, You (Maintenance department) fix" is not followed [6].

TPM Objectives:

1. Achieve Zero Defects, Zero Breakdown and Zero accidents in all functional areas of the organization.

2. Involve people in all levels of organization.

3. Form different teams to reduce defects and Self Maintenance.

Direct benefits of TPM:

1. Increase productivity and OPE (Overall Plant Efficiency) by 1.5 or 2 times.
2. Rectify customer complaints.
3. Reduce the manufacturing cost by 30%.
4. Satisfy the customers needs by 100 % (Delivering the right quantity at the right time, in the required quality.)

Indirect benefits of TPM:

1. Higher confidence level among the employees.
2. Keep the work place clean, neat and attractive.
3. Favorable change in the attitude of the operators.
4. Achieve goals by working as team.
5. Horizontal deployment of a new concept in all areas of the organization.
6. Share knowledge and experience.
7. The workers get a feeling of owning the machine.

2.4 Different types of maintenance

Types of maintenance :

1. Breakdown maintenance :

It means that people waits until equipment fails and repair it. Such a thing could be used when the equipment failure does not significantly affect the operation or production or generate any significant loss other than repair cost [6].

2. Preventive maintenance (1951):

It is a daily maintenance (cleaning, inspection, oiling and re-tightening), design to retain the healthy condition of equipment and prevent failure through the prevention of deterioration, periodic inspection or equipment condition diagnosis, to measure deterioration. It is further divided into periodic maintenance and predictive maintenance. Just like human life is extended by preventive medicine, the equipment service life can be prolonged by doing preventive maintenance [6].

2a. Periodic maintenance (Time based maintenance - TBM) :

Time based maintenance consists of periodically inspecting, servicing and cleaning equipment and replacing parts to prevent sudden failure and process problems [6].

2b. Predictive maintenance :

This is a method in which the service life of important part is predicted based on inspection or diagnosis, in order to use the parts to the limit of their service life. Compared to periodic maintenance, predictive maintenance is condition based maintenance. It manages trend values, by measuring and analyzing data about deterioration and employs a surveillance system, designed to monitor conditions through an on-line system [6].

3. Corrective maintenance (1957) :

It improves equipment and its components so that preventive maintenance can be carried out reliably. Equipment with design weakness must be redesigned to improve reliability or improving maintainability [6].

4. Maintenance prevention (1960):

It indicates the design of new equipment. Weakness of current machines are sufficiently studied (on site information leading to failure prevention, easier maintenance and prevents of defects, safety and ease of manufacturing) and are incorporated before commissioning a new equipment [6].

2.5 Six Big Losses: The following table lists the Six Big Losses, and shows how they relate to the OEE Loss categories [6].

Table 2.1: Six Big Losses

Six Big Loss Category	OEE Loss Category	Event Examples	Comment
Breakdowns	Down Time Loss	-Tooling Failures -Unplanned Maintenance - General Breakdowns - Equipment Failure	There is flexibility on where to set the threshold between a Breakdown (Down Time Loss) and a Small Stop (Speed Loss).
Setup and Adjustments	Down Time Loss	-Setup/Changeover - Material Shortages - Operator Shortages - Major Adjustments - Warm-Up Time	This loss is often addressed through setup time reduction programs.
Small Stops	Speed Loss	-Obstructed Product Flow - Component Jams -Misfeeds - Sensor Blocked - Delivery Blocked - Cleaning/Checking	Typically only includes stops that are under five minutes and that do not require maintenance personnel.
Reduced Speed	Speed Loss	-Rough Running - Under Nameplate Capacity - Under Design Capacity - Equipment Wear - Operator Inefficiency	Anything that keeps the process from running at its theoretical maximum speed (a.k.a. Ideal Run Rate or Nameplate Capacity).
Startup Rejects	Quality Loss	-Scrap - Rework -In-Process Damage - In-Process Expiration - Incorrect Assembly	Rejects during warm-up, startup or other early production. May be due to improper setup, warm-up period, etc.
Production Rejects	Quality Loss	- Scrap - Rework - In-Process Damage - In-Process Expiration - Incorrect Assembly	Rejects during steady-state production.

2.5.1 Defining the Six Big Losses [6]

One of the major goals of TPM and OEE programs is to reduce and/or eliminate the Six Big Losses – the most common causes of efficiency loss in manufacturing. Six Big Losses are and some of the Events that contribute to these losses, we can focus on ways to monitor and correct them. Categorizing data makes loss analysis much easier, and a key goal should be fast and efficient data collection, with data put it to use throughout the day and in real-time.

2.5.1.1 Breakdowns

Eliminating unplanned Down Time is critical to improving OEE. Other OEE Factors cannot be addressed if the process is down. It is not only important to know how much down time a process is experiencing (and when) but also to be able to attribute the lost time to the specific source or reason for the loss (tabulated through Reason Codes). With Down Time and Reason Code data tabulated, Root Cause Analysis is applied starting with the most severe loss categories.

2.5.1.2 Setup and Adjustments

Setup and Adjustment time is generally measured as the time between the last good parts produced before Setup to the first consistent good parts produced after Setup. This often includes substantial adjustment and/or warm-up time in order to consistently produce parts that meet quality standards.

Many companies use creative methods of reducing Setup Time including assembling changeover carts with all tools and supplies necessary for the changeover in one place, pinned or marked settings so that coarse adjustments are no longer necessary, and use of prefabricated setup gauges.

2.5.1.3 Small Stops and Reduced Speed

Small Stops and Reduced Speed are the most difficult of the Six Big Losses to monitor and record. Cycle Time Analysis should be utilized to pinpoint these loss types. In most processes recording data for Cycle Time Analysis needs to be automated since cycles are quick and repetitive events that do not leave adequate time for manual data-logging.

By comparing all completed cycles to the Ideal Cycle Time and filtering the data through a Small Stop Threshold and Reduced Speed Threshold the errant cycles can be automatically categorized for analysis. The reason for analyzing Small Stops separately from Reduced Speed is that the root causes are typically very different, as can be seen from the Event Examples in the previous table.

2.5.1.4 Startup Rejects and Production Rejects

Startup Rejects and Production Rejects are differentiated, since often the root causes are different between startup and steady-state production. Parts that require rework of any kind should be considered rejects. Tracking when rejects occur during a shift and/or job run can help pinpoint potential causes, and in many cases patterns will be discovered.

Often a Six Sigma program, where a common metric is achieving a defect rate of less than 3.4 defects per million “opportunities”, is used to focus attention on a goal of achieving ”near perfect” quality.

2.6 OEE (Overall Equipment Efficiency) [6]

OEE is a "best practices" way to monitor and improve the effectiveness of manufacturing processes (i.e. machines, manufacturing cells, assembly lines).

OEE is simple and practical. It takes the most common and important sources of manufacturing productivity loss, places them into three primary categories and distills them into metrics that provide an excellent gauge for measuring where you are - and how you can improve.

OEE is frequently used as a key metric in TPM (Total Productive Maintenance) and Lean Manufacturing programs and gives a consistent way to measure the effectiveness of TPM and other initiatives by providing an overall framework for measuring production efficiency.

OEE Factors introduces Availability, Performance, and Quality the metrics that will use to measure plant's efficiency and effectiveness. It provides a visual overview of the key productivity losses that occur in the typical manufacturing environment. It starts with Plant Operating Time and ends at Fully Productive Time, showing the sources of productivity loss that occur in between. Six Big Losses describes the most common causes for efficiency loss – almost always found in today's manufacturing environment. Six root causes of loss are presented, each directly related to an OEE Factor.

2.6.1 The availability of the equipment [6]

Plant Operating Time

From Plant Operating Time, a category of time called Planned Shut Down is subtracted, which includes all events that should be excluded from efficiency analysis because there was no intention of running production (e.g. breaks, lunch, scheduled maintenance, or periods where there is nothing to produce). The remaining available time is your Planned Production Time.

Planned Production Time

OEE begins with Planned Production Time and scrutinizes efficiency and productivity losses that occur, with the goal of reducing or eliminating these losses. There are three general categories of loss to consider - Down Time Loss, Speed Loss and Quality Loss.

Availability:

Availability takes into account Down Time Loss, which includes any Events that stop planned production for an appreciable length of time (usually several minutes – long enough to log). Examples include equipment failures, material shortages, and changeover time. Changeover time is included in OEE analysis, since it is a form of down time. While it may not be possible to eliminate changeover time, in most cases it can be reduced. The remaining available time is called Operating Time.

2.6.2 The performance of the equipment

Performance takes into account Speed Loss, which includes any factors that cause the process to operate at less than the maximum possible speed, when running. Examples include machine wear, substandard materials, mis-feeds, and operator inefficiency. The remaining available time is called Net Operating Time.

2.6.3 The quality of the product

Quality takes into account Quality Loss, which accounts for produced pieces that do not meet quality standards, including pieces that require rework. The remaining time is called Fully Productive Time. The goal is to maximize Fully Productive Time.

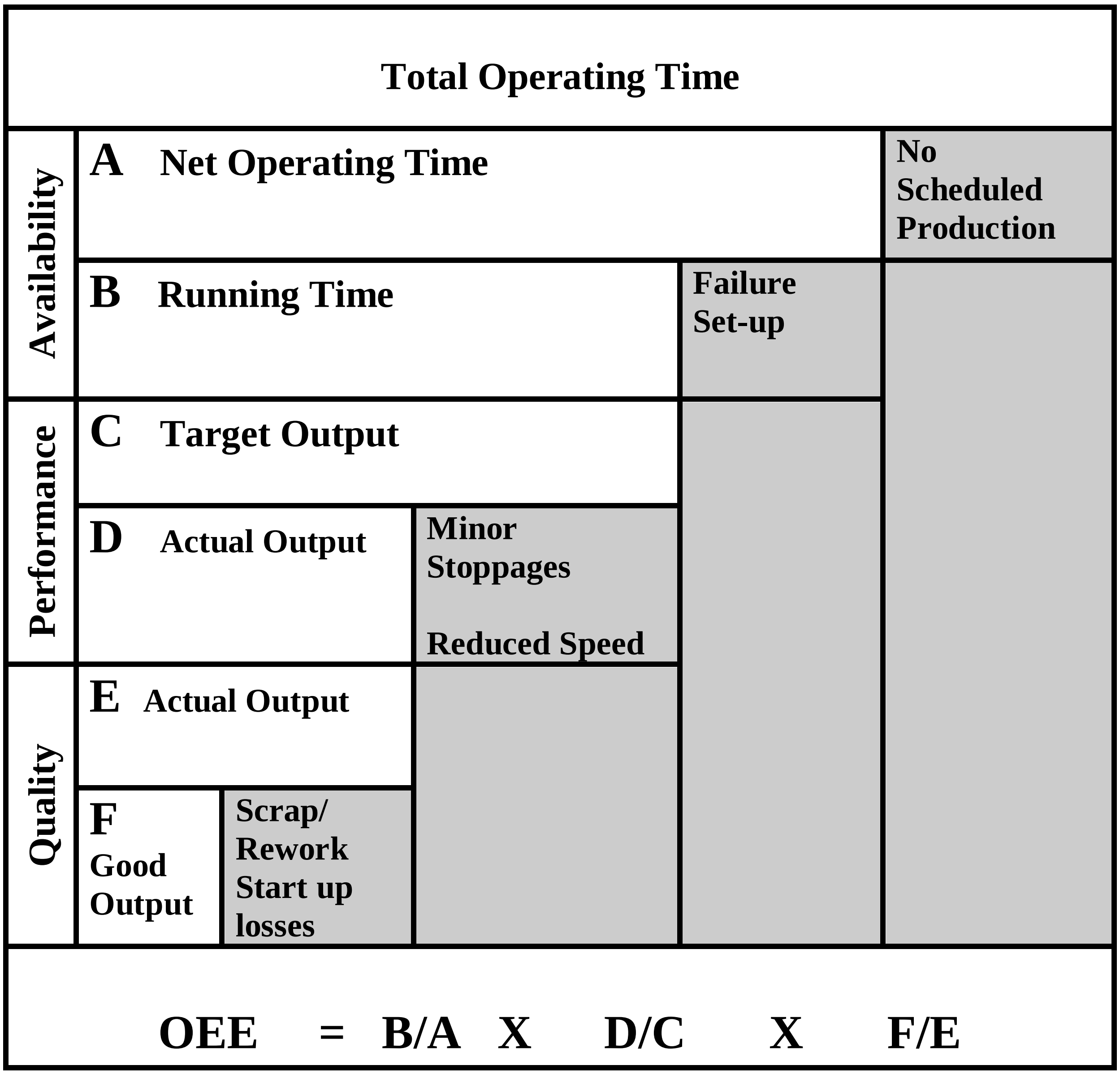


Figure 2.1: Components of Overall Equipment Efficiency [6].

2.4 Calculation of Overall Equipment Efficiency (OEE) [6]

There are three key factors for calculation of Overall Equipment Efficiency (OEE). They are: Availability, Performance, and Quality.

The availability is calculated in the following way:

1. Availability

Availability takes into account Down Time Loss, and is calculated as:

Availability = Operating Time / Planned Production Time

2. Performance

Performance takes into account Speed Loss, and is calculated as:

Performance = Ideal Cycle Time / (Operating Time / Total Pieces)

Ideal Cycle Time is the minimum cycle time that a process can be expected to achieve in optimal circumstances. It is sometimes called Design Cycle Time and Theoretical Cycle Time.

Since Run Rate is the reciprocal of Cycle Time, Performance can also be calculated as:

Performance = (Total Pieces / Operating Time) / Ideal Run Rate

Performance is limited to 100%, to ensure that if an error is made in specifying the Ideal Cycle Time or Ideal Run Rate the effect on OEE will be limited.

3. Quality

Quality takes into account Quality Loss, and is calculated as:

Quality = Good Pieces / Total Pieces

OEE

OEE takes into account all three OEE Factors, and is calculated as:

OEE = Availability x Performance x Quality

Chapter 3

Knitting Machine Overview and Data Collection

3.1 Knitting Overview

The process of forming a fabric by the intermeshing of loops of yarn is Knitting. [8] And a machine for the production of fabrics or garments by warp or weft knitting is knitting machine.

There are four primary structures from which all weft Knitted fabrics and garments are derived. They are: plain, rib, interlock and purl.

Plain is produced by the needles knitting as a single set, drawing the loops away from the technical back and towards the technical face side of the fabric.

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

Interlock was originally derived from rib but requires a special arrangement of needles knitting back-to-back in an alternate sequence of two sets, so that the two courses of loops show wales of face loops on each side of the fabric exactly in line with each other , thus hiding the appearance of the reverse loops.

Purl is the only structure having certain wales containing both face and reverse meshed loops. [7]

3.1.1 Plain Structure

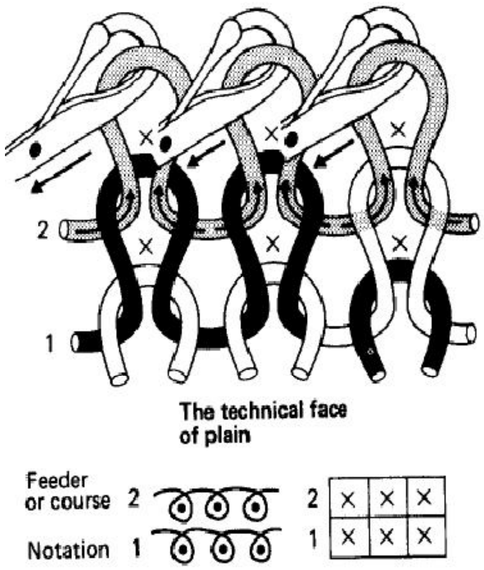
Its technical face (Fig. 3.1) is smooth, with side limbs of the needle loops having the appearance of column of V's in the wales. On the technical back, the heads of the needle loops and the bases of the sinker loops form columns of interlocking semi-circles (Fig. 3.2).

Plain can be unroved from the course knitted last by pulling the needle loops through from the technical back, or from the course knitted first by pulling the sinker loops through from the technical face side.

If the yarn breaks, needle loops successively unmesh down a wale and sinker loops unmesh up a wale, this structural breakdown is termed laddering.

When the fabric is cut, the fabric curls towards the face at the top and bottom and towards the back at the sides.

When the fabric is cut, the loops are no longer held so that the fabric curls towards the face at the top and bottom and towards the back at the sides. [7]



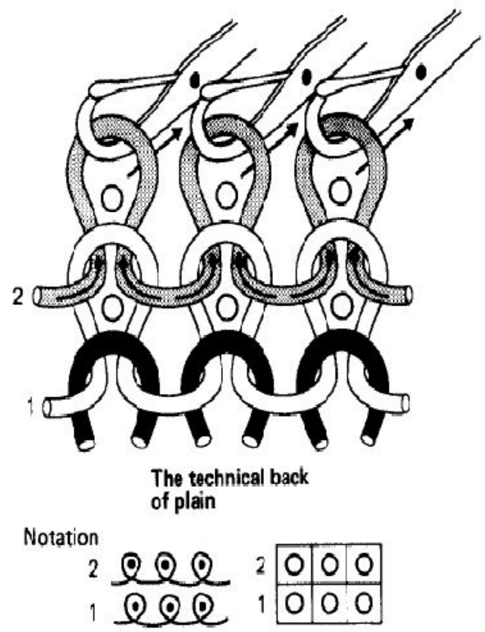


Figure 3.1: The technical face of plain [7]. **Figure 3.2:** The technical back of plain [7].

3.1.2 Production of single-jersey fabric on a circular latch needle machine [7]

Most single-jersey fabric is produced on circular machines whose latch needle cylinder and sinker ring revolve through the stationary knitting cam systems that, together with their yarn feeders, are situated at regular intervals around the circumference of the cylinder. The yarn is supplied from cones placed either on an integral overhead bobbin stand or on a free standing creel, though tensioners, stop motions and guide eyes down to the feeder guides.

The fabric, in tubular form, is drawn downwards from inside the needle cylinder by tension rollers and is wound onto the fabric-batching roller of the winding-down frame. The winding-down mechanism revolves in unison with the cylinder and fabric tube and a rack-lever operated via cam-followers running on the underside of a profiled cam ring. As the sinker cam-plate is mounted outside on the needle circle, the centre of the cylinder is open and the machine is referred to as an open top or sinker top machine.

The most popular machine diameter is 26 inches (66 mm) giving an approximate finished fabric width 60-70 inches.

Figure below illustrates some of the features of a modern circular fabric-producing machine that ensure that high quality fabric is knitted at speed with the minimum of supervision:

1, 2 The top (1) and bottom (2) stop motions. These are spring loaded yarn supports that pivot downwards, when the yarn end breaks or its tension is increased. This action releases the surplus yarn to the feeder, thus preventing a press-off, and simultaneously completes a circuit which stops the machine and illuminates an indicator warning light.

3 Various spring-loaded detector points. These are carefully positioned around the cylinder according to their particular function. A pointer is tripped to stop the machine by a fault or malfunctioning element such as yarn slubs, fabric lump, needle head, latch spoon, etc.

4 The tape positive feed (4A) This provides three different speeds (course length) and is driven and can be adjusted from the drive arrangement (4B).

5 The cylinder needle cam system for each feed – contained in a single replaceable section and having an exterior adjustment for the stitch cam slide.

6 The automatic lubricating system.

7 Start, stop and inching buttons.

8 The cam-driven fabric winding down mechanism, which revolves with the fabric tube.

9 The revolution counters for each of the three shifts and a pre-set counter for stopping the machine on completion of a specific fabric length (in course).

10 Side creel (Optional)

11 Lint blower. This reduces the incidence of knitted-in lint slubs, to improve quality when using open-end spun yarns. It also reduces cross-contamination by fibre from other machines.

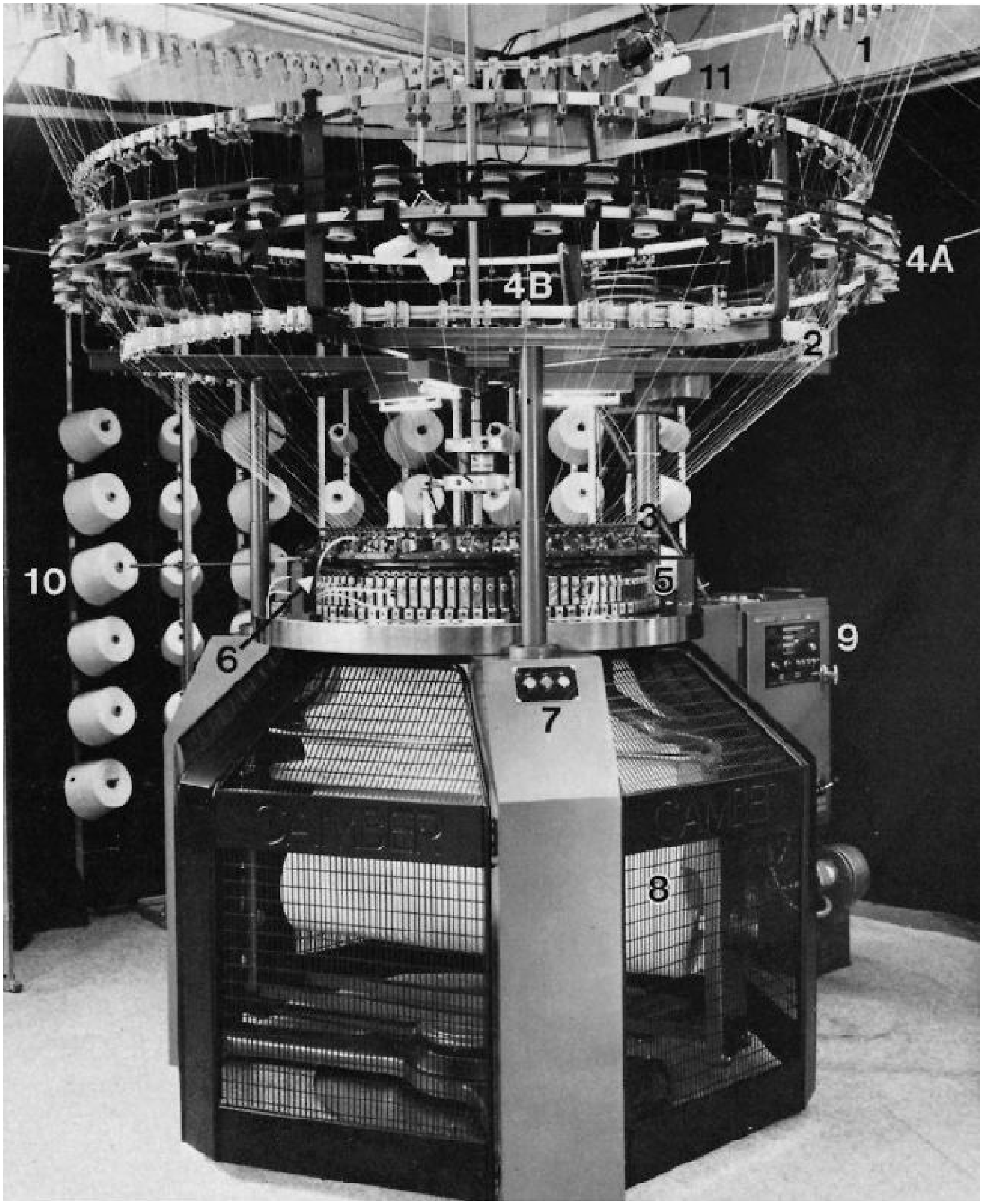


Figure 3.3: The modern circular single jersey fabric machine [7].

3.1.3 The Knitting head [7]

Following figure shows a cross section of the knitting head all of whose stationary parts are shaded.

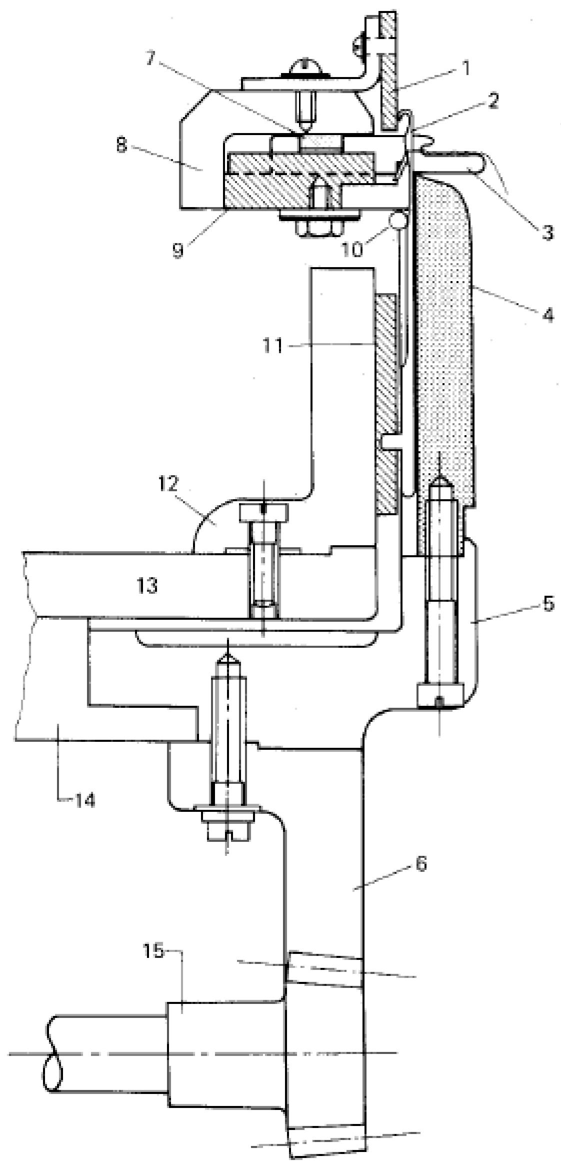


Figure 3.4: Cross-section of knitting head of a single jersey machine [7].

1. Yarn feeder guide, which associated with its own set of knitting cams.

2. Latch needle.

3. Holding down sinker – one between every needle space.

4. Needle cylinder

5. Cylinder driving wheel.

6. Cylinder driving gear

7. Sinker operating cams, which form a raised track operating in the recess of the sinker.

8. Sinker cam-cap.

9. Sinker trick ring, which is simply and directly attached to the outside top of the needle cylinder thus causing the sinkers to revolve in unison with the needles.

10. Needle retaining spring.

11. Needle-operating cams which, like the sinker cams, are stationary.

12. Cam-box.

13. Cam-plate.

14. Head-plate

15. Cylinder driving pinion attached to the main drive shaft.

3.1.4 The features of the latch needle [7]

The latch needle has nine main features (Fig.)

1 The hook, which draws and retains the new loop.

2 The slot or saw cut, which receive the latch blade (not illustrated).

3 The cheeks or slot walls, which are either punched or riveted to fulcrum the latch- blade (not illustrated).

4 The rivet, which may be plain or threaded. This has been dispensed with on most plate metal needles, by punching in the slot walls to retain the latch blade.

5 The latch-blade, which locates the latch in needle.

6 The latch spoon, which is an extension of the blade, and bridges the gap between the hook and the stem covering the hook when closed, as shown in broken lines.

7 The stem, which carries the loop in the clearing or rest position.

8 The butt, which enables the needle to be reciprocated when contacted by cam profiles on either side of it, forming a track.

9 The tail, which is an extension below the butt, giving additional support to the needle and keeping the needle in its trick.

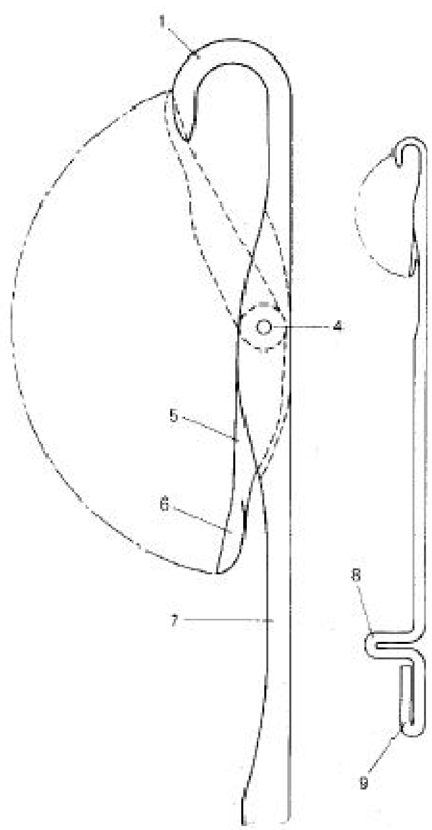


Figure 3.5: Main features of the latch needle [7].

3.1.5 **The Knitting action** [7]

Figure 3.6 shows the knitting action of a latch needle and holding-down sinker during the production of a course of plain fabric.

(a) Tucking in the hook or rest position. The sinker is forward, holding down the old loop whilst the needle has been raised from the rest position.

(b) Clearing. The needle has been raised to its highest position clearing the old loop from its latch.

(c) Yarn feeding. The sinker is partially withdrawn allowing the feeder to present its yarn to the descending needle hook and also freeing the old loop so that it can slide up the needle stem and under the open latch spoon.

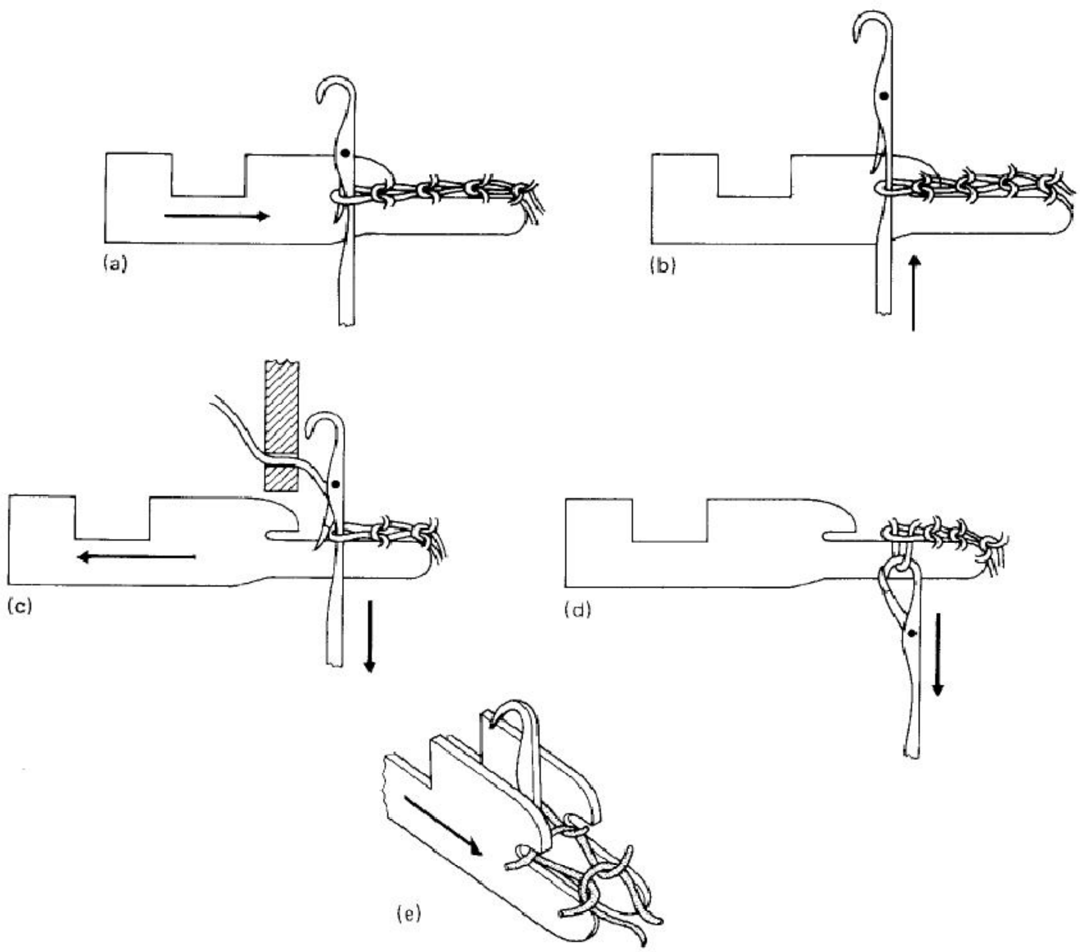


Figure 3.6: Knitting cycle of a single jersey latch needle machine [7].

(d) Knock-over. The sinker is fully withdrawn whilst the needle descends to knock-over its old loop on the sinker belly.

(e) Holding-down. The sinker moves forward to hold down the new loop in its throat whilst the needle rises under the influence of the upthrow cam to the rest position where the head of the open hook just protrudes above the sinker belly.

3.1.6 Description of causes of knitting Machine Stoppage:

1. Cleaning by Blower:

When the knitting machine run - it accumulates fiber fly, dirt and dust in the trick of cylinder and needle. So the machine needs to be cleaned with air blow when needed or a particular interval of time. Otherwise fabric produced by the knitting machine will contain unwanted dirt-mark or have a fuzzy appearance. Moreover if the fly and dirt accumulates in the needle - the knitting action of the needle will be faulty. It will limit the needle movement through the cams. It will result – different fabric faults – like – drop stitches which may lead to set-off (Cloth fall-out) problem.

To avoid these and to facilitate the knitting action of needle – the machines are generally cleaned by air-blow after every shift of 8 hours. Sometime it is done on the basis of need.

We can reduce the time of cleaning by blower - if we can reduce the amount of fly, dirt and dust accumulation on the knitting machine.

Among fiber fly, dirt and dust – fiber fly is the major amount and that will lead us – the machine to be cleaned-up by blower.

If we want to reduce the time for cleaning by blower – we have to reduce the amount of fiber fly generation.

We have to consider yarn as it is the source of fiber fly generation. If the yarn has less twist – then the amount of fiber fly generation will be more. Generally coarser yarn (lower yarn count) has less twist than the finer yarn (Higher yarn count).

Again type of yarn affects the amount of fiber-fly generation. Combed yarn produces less fiber-fly than the carded yarn.

Waxed yarn produces less fiber-fly than the un-waxed yarn. Dry yarn produces more fiber fly than the conditioned yarn.

In knitting machine - the speed of machine and number of feeder is important factor for fiber-fly generation. The higher the speed of machine and number of feeder – more the fiber-fly generation.

The atmospheric condition of the knitting room is to be controlled if we want to reduce the amount of fiber-fly generation. If the temperature of the room is high – the yarn will be dry – leading to higher amount of fiber-fly generation.

Again if the air is dry ie, less moisture in the air – the more fiber-fly will generate. Fiber fly generation means loss of fiber from the yarn which may lead to another problem – yarn breakage.

More the fiber fly generation – more time will be required to clean the machine by blower. Again the fiber-fly will clog the trick of cylinder which will lead to needle breakage.

2. Yarn Breakage:

Not only fiber-fly generation, unwaxed yarn breaks more. Generally the knitting yarns waxed with paraffin wax to decrease the yarn breakage rate. The cause of yarn breakage is due to increase in friction with needle, guide and different tension devices.

During knitting the yarn passes through different yarn guide, yarn tensioners and finally knitted by the needle. If the above mentioned machine parts have sharp edges – the yarn will break. Again if the tension of the yarn is high the yarn breakage rate will be high.

If the speed of knitting machine is high the yarn breakage rate will be high.

If the atmospheric temperature is high and contains less moisture - the yarn will be dry and will lead to yarn breakage.

If temperature is high in the knitting room the yarn will be dry and loss of fiber from the yarn i.e. fiber fly generation will be more. This fiber fly is the loss of fiber from the yarn. This leads to yarn strength loss which finally results in yarn breakage. Again if the moisture in the knitting room is less than adequate the yarn will be dry. In case of cotton yarn the strength will be less. The yarn will break frequently.

When a yarn breaks in a feeder the knitter have to stop the knitting machine, repair the yarn and then start the machine again. This will increase the non-productive time of knitting machine.

3. Needle Breakage:

If the tension in yarn is more – it will cause the needle to bend. The bent needle will lead to needle breakage.

The yarn by which we are producing fabric is also a source of fiber-fly. This fiber-fly mixed with oil and lubricants of machine may limit the needle movement by clogging the cam track and will lead to needle breakage.

Yarn containing large knots, slubs causes needle to break.

Again the grease and lubricants used in the machine may mix-up with the fiber-fly and clog the cylinder trick and cam track. This may lead to needle breakage and faulty knitting action. So the oiling and greasing must be done carefully and the lines and pipes should not have any leakage.

If the cam is loose or worn-out the needle breakage rate will increase.

In a clean knitting room will produce less dirt and dust than a dirty knitting room. The dirt and dust will clog the movement of needle and will result needle breakage.

When a needle breaks, the knitter has to stop the machine then change it with a new needle.

There are three main areas to control to reduce the time of stoppage.

4. Set-off

In dry atmosphere the yarn acts lively which leads the newly formed loop to drop out from needle. Again set-up problem will occur if the needle latch does not open clearly.

3.1.7 Defects in Knit fabric and their causes: [8]

Defects in circular knit fabric can be caused in various ways. Sometimes they are related to more than one cause. The sources of faults could be:

1. Faults in yarn and the yarn package
2. Yarn feeding and yarn feed regulator
3. Machine setting and pattern defects
4. Machine maintenance
5. Climatic conditions in the knitting plant

The most common faults are

1. Broken ends, holes or cracks
2. Drop stitches
3. Cloth fall-out
4. Snags
5. Tuck or double loops
6. Bunching up
7. Vertical stripes
8. Horizontal stripes
9. Soil stripes
10. Colored-fly
11. Deformed or tilted loops

1. Broken ends, holes or cracks:

1. Holes are the result of cracks or yarn breakages during loop formation in the region of needle hook.
2. Large holes could be caused by weak places in the yarn, leading the yarn to break during loop formation.
3. Small holes are often the result of a broken yarn before or after a knot or splice, since the yarn end with the knot or splice sits tightly in the last stitch. The knot or splice

gets stuck in the needle and raises tension and the yarn breaks before the knot or splice.

4. Again knots could have been too short yarn ends. They can loosen themselves, especially when they are not tight enough.
5. For a given knitting speed the ability of the yarn to slide is not sufficient. For this reason the knitting yarns are waxed. Insufficient waxing leads to increase in frictional forces among needle and yarn. So, yarn breaks during loop formation leading cracks or holes in fabric.
6. Same thing will happen if the knit yarn is stored for a long time in dry atmosphere.
7. Again cracks or holes can be caused by soft and sticky cones, cones not being centered while creeling, unsuitable yarn guide elements etc.
8. Cracks and holes can also form if the yarn tension is too high in relation to the structure and the breaking strength of the yarn.
9. Cracks or holes will also result if the setting of yarn feeder is faulty in such a way, that a needle can run into the yarn feeder with a closed latch.
10. Edgy surface in yarn feeder bore or guide elements will cause damage of yarn will finally result in cracks or holes.
11. Cracks or holes will result if the fabric is pulled down too strongly or in jerky movements due to defective setting or bad maintenance.

Drop stitches:

1. If the yarn is stiff, it jumps away from the needle hook while being laid-in. By increasing the yarn tension this can be compensated.
2. If the yarn tension is not sufficient, the yarn can shoot forward and puff itself up between yarn feeders and needle in such a way that needle hook can not catch the yarn.
3. If the yarn feeders is not properly set. It presents yarn to the needle for being taken over at an unfavorable angle.
4. If the yarn has been threaded through the wrong bore.
5. If the fabric take-up is insufficient. For this already formed loops can hang-out before the next course is started to produce.

6. In lighter fabrics, drop stitches can also form along with cracks or holes.

Cloth fall-out:

If the yarn is not stitched by several needles lying adjacent to one another. Cloth fall out can occurs when successive needles with closed latch runs into the yarn feeder and releases the old loop out from the hooks and fails to catch the new yarn. The reason behind cloth fall-out is similar to drop stitches. When successive needles produces drop stitches then cloth fall-out occurs. This is also called fabric press-off.

Snags:

Snags mainly occurs while knitting filament yarn.

The tendency of snagging can be reduced by using coarser single yarn with lesser crimp and elasticity.

Mechanical influences due to rough surfaces on yarn guides, yarn feeders, needles, fabric take-up will result in snags.

Tuck or double stitches:

Generally this fault appears in basic and jacquard structures.

1. If yarn has poor sliding ability, it will cause this fault.
2. If the needle clearance is too small the old loops will remain on the latch-spoon which will result in tuck stitches.
3. In double jersey knitting machines, if the dial is set too high. The dial needle will pull the fabric which will cause tuck stitch to form.
4. If the loops are tight or small in case of tightly knit fabric. In this case the small old loops have a tendency for not to knock over.
5. If the fabric take-up is insufficient or has a one-sided drag on the fabric or is not continuous then this fault will occur.

Bunching-up:

If the take-up mechanism does not work properly then this fault will occur.

Vertical stripes:

1. If the yarn count is too fine for the machine gauge or stitch size is small then Vertical stripes or gaps in the fabric will occur.
2. Any faults in knitting elements like, bent needle, damaged needle, damaged sinker will result in vertical stripes.
3. If the knitting elements do not move smoothly or comes from different suppliers then this fault will occur.

Horizontal stripes:

Horizontal stripes can be caused by the yarn or by the setting of the knitting machine.

1. Any irregularity in yarn will appear as a fault in fabric as a horizontal line.
2. If the color, count or lot number is dissimilar in feeder to feeder then horizontal stripe will appear.
3. Horizontal stripe will result in if yarn tension or stitch length varies between the feeders.
4. Fabric take-up can also cause horizontal stripes, if it is jerky or is not uniform.
5. In case of double jersey knitting machine, if the machine is not mounted horizontally and the needle dial and cylinder is not centered to one another then it will cause horizontal stripes.

Soil stripes:

1. Soil stripes in the direction of the wales are solely caused by the knitting elements.
2. Sometimes the vertical soil stripes are called needle stripes as they occur when an individual needle has been replaced or automatic oiling or greasing devices are defective.
3. Dirty yarn causes horizontal soil stripes.
4. Due to machine stoppage for a long time will result soil stripes.

Colored-fly:

There are three categories of color-fly faults:

1. Sometimes seed coat fragments and leaf are present in cotton yarn. This comes from when the cotton fiber is processed. after knitting it comes in the fabric as a fault.
2. Fly coming from different stages of processing stages in yarn spinning.
3. Fly in knitting plant also causes this problem. In a congested knitting plant during knitting with different color yarn color fly will migrate to one machine to the adjacent different color fabric.

Distorted stitches:

If the relative setting of dial and cylinder is not correct in a double jersey knitting machine the stitches become deformed. The heads of the stitches are not round but lopsided. They also appear to be tilted towards the other side of the fabric.

Chapter 4

Overall Equipment Efficiency (OEE) of Knitting Machine

4.1 Different Operating Parameters of a Knitting Machine:

4.1.1 Machine Speed:

Speed and number of feeders influence the amount of production signaficantly. The calculation of production of a single jersey knitting machine is as follows:

$$\frac{\text{Stitch length X } \Pi \text{ X machine dia X gauge X No.of feeder X Machine R.P.M. X 60}}{\text{10 X 2.54 X 36 X 840 X yarn count X 2.20.46}} \text{ kg / hour [7].}$$

According to the equation, if we increase the knitting machine R.P.M. the amount of production of fabric also increases.

The R.P.M. of a knitting machine depends on: [8]

1. Type of machine.

2. Yarn count.

3. Stitch length.

4. Fabric structure.

5. Needle gauge

6. No. of feeder. etc.

The speed of machine is adjusted by recommendation of machine manufacturer and on trial and error basis. Here the speed factor plays a great role on knitting machine speed. For this knitting machine speed factor was 1050. The speed of the machine was calculated by following calculation:

$$\frac{\text{Speed Factor of the Kntting machine}}{\text{Diameter of the knitting machine}} \text{ X } 0.88\%$$

$$= \frac{1050}{22} \text{ X } 0.88$$

= 42 R.P.M.

In this project work, different datas were collected by running the knitting machine at 40 R.P.M., 42 R.P.M., and 44 R.P.M.

The Overall Equipment Efficiencies (OEE) were calculated from the datas. Then their feasability were compared by analysing different factors.

4.1.2 Number of feeders:

Number of feeders also influences the production of a knitting machine signaficantly. Higher the number of feeders the more the production of fabric. The number of feeders depends on the diameter of knitting machine. Again one has to consider the cam angle for accommodating total number of feeders. Some problem arises in single jersey knitting machine with higher number of feeders. This causes spirality in single jersey knit fabric [8].

4.1.3 Type of Yarn:

In this project work different data were collected from knitting section by knitting with waxed and un-waxed yarns. Waxed yarns are slippery and yields less friction with machine parts and knitting elements. For this reason waxed yarn breaks less frequently than the unwaxed yarn. During winding of cone from spinning bobbin wax is applied on yarn at the amount of 0.1% – 0.3% on the weight of yarn. Generally paraffin wax is used for waxing knitting yarns [8].

4.2 Data Collection

4.2.1 Data Accumulation

During study on variation of knitting machine speed a single machine of 22” diameter and 24 gauge was selected. Then data was collected in data collection sheet shown in table 4.1. For a particular knitting machine speed (R.P.M.), data was collected for 12 hours. Data was collected for two days for each speed. In this way a collection of data was accumulated for 24 hours for each machine speed. For this study a set of data was collected for total three days from one knitting machine.

To study by varying the number of feeders, two knitting machine was sected. First one had 72 feeders and the other had 75 feeders. Data was collected continuously on each machine for for 24 hours in the data collection sheet shown in Table 4.1. For this study a set of data was collected for one day from two kntting machines.

Finally, to study on variation of yarn type, a single machine of 22” diameter and 24 gauge was selected. Then data was collected in data collection sheet shown in table 4.1. For a particular type of yarn the machine was run at different knitting machine speed (R.P.M.), data was collected for 12 hours. Data was collected for two days for each speed. In this way a collection of data was accumulated for 24 hours for each machine speed and one type of yarn. For this study a set of data was collected for six days.

Table 4.1: Example of an data collection sheet.

Machine No.		10		
Brand:	Jiunn Long		**Date:**	20-07-2013
Model:			**Shift:**	A
Dia:	25”		**No. of feeder**	75
Gauge:	24			
Yarn type Count& Lot	**Stitch Length (mm)**	**R.P.M.**	**Cause of Stoppage**	**Duration of Stoppage in minutes**
24/1	2.62	26	Yarn breakage	1
Carded			Yarn breakage	1
Badsha			Set-off	2
Lot#42A			Cleaning by blower and roll cutting	
			Yarn breakage	1
			Yarn breakage	1
			Yarn breakage	1

Production in Kgs: 90

The data was then organized in the following tables for analyzing:

Table 4.2: Production and different stoppage time at knitting machine speed 40 R.P.M. (for waxed yarn)

M/C No	**43**
M/C DiaXGG	**22"x24GG**
M/C RPM	**40**
Yarn Type	**24'sKH MSML(Waxing)**
Lot No	**A-12**
S.L	**30.5**

DATE:	18.04.11

Start Time	8.00 AM
End Time	8.00PM

Roll No	Weight(Kg)	Yarn Breakage	Time(Min)	Set off	Time(Min)	M/C Cleaning/Roll Cutting	Time(Min)	Others	Time(Min)
1	20.7	3	4	1	2	9.19-9.27	8		
2	20.9	2	2	0	0	10.32-10.42	10		
3	21	2	2	0	0	11.47-11.58	11		
4	22.7	3	4	0	0	1.15-1.18	3		
5	22.2	5	5	1	4	2.50-3.00	10	Yarn Joining(13)	7
6	24.1	5	5	1	2	4.33-4.42	9	Yarn Joining(4)	2
7	18.7	4	4	0	0	5.55-6.00	5		
8	19.5	2	2	0	0	6.46-6.49	3		
9	16.1	2	2	2	9	7.50-8.00	10		
10									
Total=	185.9	28	30	5	17		69		9

Table 4.3: Production and different stoppage time at knitting machine speed 40 R.P.M. (for waxed yarn)

M/C No	**43**
M/C DiaXGG	**22"x24GG**
M/C RPM	**40**
Yarn Type	**24'sKH MSML(Waxing)**
Lot No	**A-12**
S.L	**30.5**

DATE:	19.04.11

Start Time	8.00 AM
End Time	8.00PM

Roll No	Weight(Kg)	Yarn Breakage	Time(Min)	Set off	Time(Min)	M/C Cleaning/Roll Cutting	Time(Min)	Others	Time(Min)
1	18.4	1	1	4	16	9.35-9.43	8	Air Pipe Problem	10
2	19.5	1	1	0	0	10.45-10.50	5		
3	21.3	3	3	0	0	12.00-12.05	5	Yarn Joining(7)	4
4	20.5	5	6	0	0	1.05-1.15	10	Yarn Joining(7)	4
5	23.4	6	7	1	5	2.38-2.44	6		
6	22.1	1	1	1	3	4.00-4.05	5	M/C Problem	4
7	21.3	1	1	0	0	5.09-5.20	11		
8	22.2	4	4	0	0	6.30-6.35	5		
9	22.5	5	6	1	2	7.55-8.00	5	Yarn Joining(3)	2
10									
Total=	191.2	27	30	7	26		60		24

Table 4.4: Production and different stoppage time at knitting machine speed 44 R.P.M. (for waxed yarn)

M/C No	**43**
M/C DiaXGG	**22"x24GG**
M/C RPM	**44**
Yarn Type	**24'sKH MSML(Waxing)**
Lot No	**A-12**
S.L	**30.5**

DATE:	21.04.11

Start Time	8.00 AM
End Time	8.00PM

Roll No	Weight(Kg)	Yarn Breakage	Time(Min)	Set off	Time(Min)	M/C Cleaning/Roll Cutting	Time(Min)	Others	Time(Min)
1	23.6	9	9	0	0	9.10-9.20	10		
2	24.8	2	2	0	0	10.29-10.36	7		
3	24.5	7	7	2	11	12.13-12.20	7	Yarn Joining(2)	1
4	22.5	2	2	0	0	1.30-1.40	10	Yarn Joining(6)& Needle Broken	8
5	21.9	6	6	0	0	2.47-2.51	4		
6	23.9	6	6	1	2	4.04-4.14	10		
7	24.7	8	8	0	0	5.30-5.40	10		
8	24.3	1	1	1	3	6.50-6.58	8		
9	14	6	6	1	8	7.55-8.00	5	Yarn Joining(6)&Star Hole Problem	13
10									
Total=	204.2	47	47	5	24		71		22

Table 4.5: Production and different stoppage time at knitting machine speed 44 R.P.M. (for waxed yarn)

M/C No	**43**
M/C DiaXGG	**22"x24GG**
M/C RPM	**44**
Yarn Type	**24'sKH MSML(Waxing)**
Lot No	**A-12**
S.L	**30.5**

DATE:	23.04.11

Start Time	8.00 AM
End Time	8.00PM

Roll No	Weight(Kg)	Yarn Breakage	Time(Min)	Set off	Time(Min)	M/C Cleaning/Roll Cutting	Time(Min)	Others	Time(Min)
1	24.9	3	3	0	0	9.25-9.32	7	M/C Clean	10
2	26.5	1	1	0	0	10.51-11.00	9	Needle Broken	5
3	25.1	5	5	0	0	12.17-12.26	11	Yarn Joining(8)	4
4	25.3	5	5	1	3	2.05-2.12	7	Yarn Joining(17)	9
5	24.5	5	5	1	4	3.33-3.40	7	Needle Broken	9
6	26.5	3	3	0	0	4.00-4.07	7		
7	24.5	6	6	0	0	6.20-6.25	5		
8	27.2	4	4	0	0	7.55-8.00	5		
Total=	204.5	32	32	2	7		58		37

Table 4.6: Production and different stoppage time at knitting machine speed 42 R.P.M. (for waxed yarn)

M/C No	**43**
M/C DiaXGG	**22"x24GG**
M/C RPM	**42**
Yarn Type	**24'sKH MSML(Waxing)**
Lot No	**A-12**
S.L	**30.5**

DATE:	24.04.11

Start Time	8.00 AM
End Time	8.00PM

Roll No	Weight(Kg)	Yarn Breakage	Time(Min)	Set off	Time(Min)	M/C Cleaning/Roll Cutting	Time(Min)	Others	Time(Min)
1	22.2	8	8	0	0	9.30-9.40	10	Yarn Joining(8)& M/C Clean	14
2	25.1	4	4	1	4	11.10-11.18	8	Yarn Joining(5)	3
3	25.3	4	4	0	0	12.40-12.50	10		0
4	26.4	2	2	0	0	2.10-2.19	9		0
5	24.4	2	2	0	0	3.23-3.32	9	Needle Broken	5
6	25	4	4	1	3	4.52-5.00	8	Oil Problem	30
7	20.5	5	5	2	8	6.25-6.34	9	Yarn Joining(13)	8
8	20.6	2	2	1	2	7.55-8.00	5	Yarn Joining(3)	2
Total=	189.5	31	31	5	17		68		62

Table 4.7: Production and different stoppage time at knitting machine speed 42 R.P.M. (for waxed yarn)

M/C No	**43**							**DATE:**	25.04.11
M/C DiaXGG	**22"x24GG**								
M/C RPM	**42**							**Start Time**	8.00 AM
Yarn Type	**24'sKH MSML(Waxing)**							**End Time**	8.00PM
Lot No	**A-12**								
S.L	**30.5**								
Roll No	**Weight(Kg)**	**Yarn Breakage**	**Time(Min)**	**Set off**	**Time(Min)**	**M/C Cleaning/Roll Cutting**	**Time(Min)**	**Others**	**Time(Min)**
1	23	3	3	1	4	9.28-9.38	10	M/C Clean	5
2	22.7	2	2	1	4	10.48-10.52	4		
3	23.3	5	5	1	5	12.11-12.18	7		
4	22.6	4	4	1	2	1.28-1.35	7	Air Pipe Join	2
5	24.2	5	5	4	12	3.33-3.41	8	Yarn Joining(20)	10
6	22.4	2	2	1	4	4.50-4.58	8		
7	26.6	1	1	0	0	6.18-6.31	13		
8	26	2	2	0	0	7.55-8.00	5		
Total=	190.8	24	24	9	31		62		17

Table 4.8: Production and different stoppage time for knitting machine with 72 and 75 feeders.

M/C Brand	Jiunn Long
GG	24
M/C RPM	26
Yarn Type	24/1 Badsha Carded
Lot No	42 A
S.L	2.62

Start Time: 6:00 A.M. 21-07-2011
End time: 06: 00 A.M. 22-07-2013

	Weight(Kg)	Yarn Breakage	Time(Min)	Set off	Time(Min)	M/C Cleaning /Roll Cutting	Time(Min)	Others	Time(Min)
M/C # 9	72 Feeders								
A shift	92	8	12	1	2	5	48		11
B shift	94	3	3	1	5	5	51		0
C shift	100	6	7	1	2	4	43		0
Total	286	17	22	3	9	14	142		11
M/C # 10	75 Feeders								
A shift	83	2	2	1	2	4	44		43.5
B shift	79	11	11	3	6	2	21		0
C shift	90	12	12	1	5	4	36		10
Total	252	25	25	5	13	10	101		53.5

Table 4.9 : Production and different stoppage time at knitting machine speed 40 R.P.M. (for unwaxed yarn)

M/C No	**43**
M/C DiaXGG	**22"x24GG**
M/C RPM	**40**
Yarn Type	**24'sKH MSML (Without Waxing)**
Lot No	**A-12**
S.L	**30.5**

DATE:	30.04.11
Start Time	8.00 AM
End Time	8.00PM

Roll No	Weight(Kg)	Yarn Breakage	Time(Min)	Set off	Time(Min)	M/C Cleaning/Roll Cutting	Time(Min)	Others	Time(Min)
1	22.7	2	2	3	9	9.56-10.04	8	M/C Clean+Yarn Join(23)	17
2	23.8	4	4	0	0	11.18-11.24	6	Yarn Join(2)	1
3	24.6	4	4	0	0	12.38-12.47	9		
4	28	3	3	0	0	2.10-2.19	9	Oil Problem	9
5	24.3	3	3	0	0	3.35-3.43	8		
6	25.3	3	3	0	0	4.56-5.03	7		
7	20.7	2	2	2	9	6.36-6.40	4	Yarn Join(30)	15
8	22.4	3	3	0	0	7.50-8.00	10		
Total=	191.8	24	24	5	18	0	61	0	42

Table 4.10: Production and different stoppage time at knitting machine speed 40 R.P.M. (for unwaxed yarn)

M/C No	**43**
M/C DiaXGG	**22"x24GG**
M/C RPM	**40**
Yarn Type	**24'sKH MSML(Without Waxing)**
Lot No	**A-12**
S.L	**30.5**

DATE:	29.04.11
Start Time	8.00 AM
End Time	8.00PM

Roll No	Weight(Kg)	Yarn Breakage	Time(Min)	Set off	Time(Min)	M/C Cleaning/Roll Cutting	Time(Min)	Others	Time(Min)
1	20.8	3	3	1	3	9.25-9.32	7		
2	24	3	3	0	0	10.45-10.55	10		
3	22.1	5	5	1	5	12.30-12.37	7	Yarn Join(28)	14
4	19.4	2	2	0	0	1.35-1.45	10	Yarn Join(3)	2
5	25.3	3	3	1	3	3.08-3.15	7	ND.Broken	5
6	26.1	5	5	1	3	4.38-4.46	8		
7	22	3	3	0	0	5.58-6.06	8		
8	26.4	4	4	0	0	7.52-8.00	8		
Total=	186.1	28	28	4	14	0	65	0	21

Table 4.11: Production and different stoppage time at knitting machine speed 42 R.P.M. (for unwaxed yarn)

M/C No	**43**
M/C DiaXGG	**22"x24GG**
M/C RPM	**42**
Yarn Type	**24'sKH MSML(Without Waxing)**
Lot No	**A-12**
S.L	**30.5**

DATE:	06.05.11
Start Time	8.00 AM
End Time	8.00PM

Roll No	Weight(Kg)	Yarn Breakage	Time(Min)	Set off	Time(Min)	M/C Cleaning/Roll Cutting	Time(Min)	Others	Time(Min)
1	22	3	3	0	0	9.30-9.38	8	M/C Clean	10
2	23.6	4	4	0	0	10.48-10.57	9	Yarn Join(3)	2
3	22.8	3	3	2	8	12.42-12.50	8	Yarn Join(28)	14
4	25.7	3	3	0	0	2.04-2.13	9		
5	23.1	2	2	0	0	3.23-3.32	9		
6	24.8	4	4	1	2	4.53-5.03	10		
7	20.3	5	5	2	7	6.22-6.34	12	Yarn Join(03)+ND Broken	7
8	19.5	4	4	0	0	7.53-8.00	7	Yarn Join(09)+FanProblem	10
Total=	181.8	28	28	5	17	0	72	0	43

Table 4.12: Production and different stoppage time at knitting machine speed 42 R.P.M. (for unwaxed yarn)

M/C No	**43**
M/C DiaXGG	**22"x24GG**
M/C RPM	**42**
Yarn Type	**24'sKH MSML(Without Waxing)**
Lot No	**A-12**
S.L	**30.5**

DATE:	**07.05.11**

Start Time	**8.00 AM**
End Time	**8.00PM**

Roll No	Weight(Kg)	Yarn Breakage	Time(Min)	Set Up	Time(Min)	M/C Cleaning/Roll Cutting	Time(Min)	Others	Time(Min)
1	13.2	5	5	3	19	9.38-9.43	5	M/C Clean+YarnJoin(20)	25
2	22.5	2	2	0	0	11.00-11.05	5	Yarn Join(8)+NDBroken	8
3	22.5	4	4	0	0	12.20-12.30	10		
4	24	4	4	0	0	1.48-1.58	10		
5	27.1	2	2	0	0	3.22-3.30	8		
6	23	6	6	2	9	4.58-5.05	7		
7	22	6	6	2	5	6.38-6.46	8	Yarn Join(22)	11
8	19	6	6	1	2	7.55-8.00	5	Yarn Join(4)	2
Total=	**173.3**	**35**	**35**	**8**	**35**	**0**	**58**	**0**	**46**

Table 4.13: Production and different stoppage time at knitting machine speed 44 R.P.M. (for unwaxed yarn)

M/C No	**43**	
M/C DiaXGG	**22"x24GG**	
M/C RPM	**44**	
Yarn Type	**24'sKH MSML(Without Waxing)**	
Lot No	**A-12**	
S.L	**30.5**	

DATE:	03.05.11
Start Time	8.00 AM
End Time	8.00PM

Roll No	**Weight(Kg)**	**Yarn Breakage**	**Time(Min)**	**Set off**	**Time(Min)**	**M/C Cleaning/Roll Cutting**	**Time(Min)**	**Others**	**Time(Min)**
1	25.3	3	3	0	0	9.25-9.33	8	M/C Clean	10
2	24.8	2	2	1	7	10.45-10.56	11		
3	23	7	7	2	5	12.50-12.55	5	Yarn Join(42)	21
4	25.1	4	4	0	0	02.13-02.21	8	Nd Broken	3
5	25.1	2	2	0	0	03.35-03.42	7		
6	26.4	4	4	0	0	05.05-05.13	8		
7	24.7	5	5	0	0	06.32-06.39	7		
8	18.2	4	4	2	5	07.55-8.00	5	Yarn Join(7)	4
Total=	192.6	31	31	5	17	0	59	0	38

Table 4.14: Production and different stoppage time at knitting machine speed 44 R.P.M. (for unwaxed yarn)

M/C No	**43**
M/C DiaXGG	**22"x24GG**
M/C RPM	**44**
Yarn Type	**24'sKH MSML(Without Waxing)**
Lot No	**A-12**
S.L	**30.5**

DATE:	04.05.11
Start Time	8.00 AM
End Time	8.00PM

Roll No	Weight(Kg)	Yarn Breakage	Time(Min)	Set off	Time(Min)	M/C Cleaning/Roll Cutting	Time(Min)	Others	Time(Min)
1	23	2	2	4	10	9.57-10.06	9	M/C Clean+Yarn Join(22)	21
2	23.3	3	3	1	3	11.22-11.31	9		
3	24	4	4	0	0	12.50-1.00	10		
4	24.3	2	2	1	2	2.14-2.21	7		
5	24.5	3	3	0	0	3.30-3.38	8		
6	24.3	6	6	1	2	5.15-5.24	9	Yarn Join(10)	5
7	21	3	3	2	5	6.48-6.56	9	Yarn Join(18)	9
8	22.7	4	4	0	0	7.55-8.00	5		
Total=	187.1	27	27	9	22	0	66	0	35

4.2.2 Determination of Overall Equipment Efficiency

4.2.2.1 Determination of Overall Equipment Efficiency for different machine speed:

From the table 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7 the Overall Equipment Efficiency was calculated in the following table:

Table 4.15: Determination of Overall Equipment Efficiency varying the machine speed.

		R.P.M.	**40**	**42**	**44**
A	Running time per day	min	1440	1440	1440
B	Downtime per day	min	0	0	0
C	Loading time per day [A - B]	min	1440	1440	1440
D	Stoppage losses per day	min	265	312	298
E	Operating time per day [C - D]	min	1175	1128	1142
	Defect amount	Kg.	1.885	2.662	4.495
F	Output per day	Kg.	377.1	380.3	408.7
G	Rate of quality products	%	99.5	99.3	98.9
H	Ideal cycle time	min	2.8985	2.8985	2.8985
I	Actual cycle time	min	3.1158	2.966	2.7976
J	Actual Processing time [I * F]		1175	1128	1143.4
K	Operating speed rate [H / I * 100]	%	93.026	97.724	103.61
L	Net operating rate [J / E * 100]	%	99.997	99.997	100.12
M	Availability [E / C] * 100	%	81.597	78.333	79.306
N	Performance Efficiency [K * L *100]	%	93.023	97.722	103.73
Overall Equipment Efficiency = M* N * G * 100			75.525	76.013	81.36

The results of the calculation has been shown in table 4.16.

Table 4.16: OEE, Availability, Perfermance and quality of knitting machine at different speed (R.P.M.)

R.P.M.	OEE	Availability	Performance	Quality
40	75.52	81.59	93.02	99.50
42	76.01	78.33	97.72	99.3
44	81.36	79.30	103.73	98.90

4.2.2.2 Determination of Overall Equipment Efficiency by varying the no. of feeder:

The data from Table 4.8 was taken and the Overall Equipment Efficiency of two knitting machines were calculated in table 4.17

Table 4.17: Determination of Overall Equipment Efficiency by varying the no. of feeders.

	No. of feeders		**72**	**75**
A	Running time per day	min	1440	1440
B	Downtime per day	min	0	0
C	Loading time per day [A - B]	min	1440	1440
D	Stoppage losses per day	min	184	192.5
E	Operating time per day [C - D]	min	1256	1247.5
	Defect amount	Kg.	2.3	2.6
F	Output per day	Kg.	286	252
G	Rate of quality products	%	99.196	98.968
H	Ideal cycle time	min	4.5714	4.39
I	Actual cycle time	min	5.035	5.7142
J	Actual Processing time [I * F]		1440	1440
K	Operating speed rate [H / I * 100]	%	90.792	76.826
L	Net operating rate [J / E * 100]	%	114.65	115.43
M	Availability [E / C] * 100	%	87.222	86.632
N	Performance Efficiency [K * L *100]	%	104.09	88.68
Overall Equipment Efficiency = M* N * G * 100			90.063	76.032

Table 4.18 : OEE, Availability, Perfermance and quality of knitting machine for different no. of feeders.

No. of feeder	OEE	Availability	Performance	Quality
72	90.06	87.22	104.09	99.19
75	76.03	86.63	88.67	98.96

4.2.2.3 Determination of Overall Equipment Efficiency by varying the yarn type

1. Calculation of Overall Equipment Efficiency (O.E.E.) for different yarn type (for waxed yarn):

From the table 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7 the Overall Equipment Efficiency was calculated in the following table for waxed yarn:

Table 4.19: Determination of Overall Equipment Efficiency for different yarn type (Waxed yarn)

	Waxed Yarn	**R.P.M.**	**40**	**42**	**44**
A	Running time per day	min	1440	1440	1440
B	Downtime per day	min	0	0	0
C	Loading time per day [A - B]	min	1440	1440	1440
D	Stoppage losses per day	min	265	312	298
E	Operating time per day [C - D]	min	1175	1128	1142
	Defect amount	Kg.	1.885	2.662	4.495
F	Output per day	Kg.	377.1	380.3	408.7
G	Rate of quality products	%	99.5	99.3	98.9
H	Ideal cycle time	min	2.8985	2.8985	2.8985
I	Actual cycle time	min	3.1158	2.966	2.7976
J	Actual Processing time [I * F]		1175	1128	1143.4
K	Operating speed rate [H / I * 100]	%	93.026	97.724	103.61
L	Net operating rate [J / E * 100]	%	99.997	99.997	100.12
M	Availability [E / C] * 100	%	81.597	78.333	79.306
N	Performance Efficiency [K * L *100]	%	93.023	97.722	103.73
Overall Equipment Efficiency = M* N * G * 100			75.525	76.013	81.36

2. Calculation of Overall Equipment Efficiency (O.E.E.) for different yarn type (for unwaxed yarn):

Data was taken from Table 4.9, 4.10, 4.11, 4.12, 4.13 and 4.14 and Overall Equipment Efficiency of knitting machine was calculated in Table 4.20 for unwaxed yarn.

Table 4.20: Determination of Overall Equipment Efficiency for different yarn type (Unwaxed yarn)

	Unwaxed Yarn	**R.P.M.**	**40**	**42**	**44**
A	Running time per day	min	1440	1440	1440
B	Downtime per day	min	0	0	0
C	Loading time per day [A - B]	min	1440	1440	1440
D	Stoppage losses per day	min	241	329	295
E	Operating time per day [C - D]	min	1199	1111	1145
	Defect amount	Kg.	3.29	4.61	5.69
F	Output per day	Kg.	377.9	355.1	379.7
G	Rate of quality products	%	99.129	98.702	98.501
H	Ideal cycle time	min	2.8985	2.8985	2.8985
I	Actual cycle time	min	3.2001	3.0335	3.0335
J	Actual Processing time [I * F]		1209.3	1077.2	1151.8
K	Operating speed rate [H / I * 100]	%	90.576	95.551	95.551
L	Net operating rate [J / E * 100]	%	100.86	96.956	100.59
M	Availability [E / C] * 100	%	83.264	77.153	79.514
N	Performance Efficiency [K * L *100]	%	91.355	92.642	96.119
Overall Equipment Efficiency = M* N * G * 100			75.403	70.548	75.282

Table 4.21: OEE, Availability, Perfermance and quality of knitting machine for different yarn type.

R.P.M.	OEE		Availability		Performance		Quality	
	Waxed	Unwaxed	Waxed	Unwaxed	Waxed	Unwaxed	Waxed	Unwaxed
40	75.52	75.40	81.59	81.04	93.02	93.85	99.50	99.12
42	76.01	70.54	78.33	76.80	97.72	93.06	99.3	98.70
44	81.36	75.28	79.30	79.51	103.73	96.11	98.90	98.50

4.3 Analysis of Overall Equipment Efficiency (O.E.E.) varying different operating parameters:

4.3.1 Analysis of Overall Equipment Efficiency (O.E.E.) varying Kntting Machine Speed

1. OEE of knitting machine at different speed (R.P.M.): If we plot the OEE at different R.P.M. we obtain the following graph:

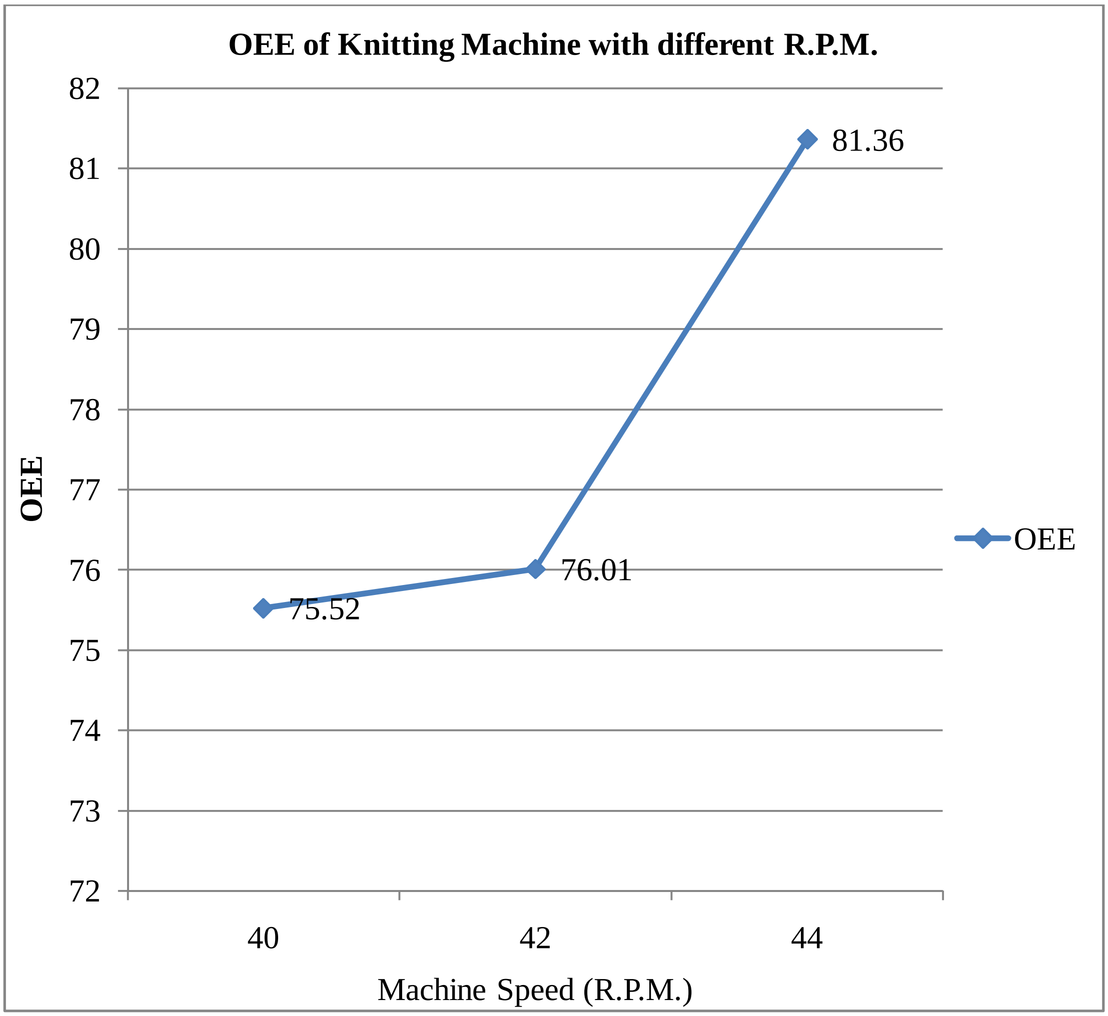


Figure 4.1: OEE of knitting machine at different speed (R.P.M.)

From the graph we can see that when the knitting machine speed (R.P.M.) has increased, the OEE has also increased. As a result of increase in availability %, performance % the OEE of knitting machine running at higher speed shows a higher value of OEE. We know that availability is the ratio between operating time and loading time expressed as a percentage. The availability percentage increased because speed has increased. It is noticeable that the stoppage time also has increased. But the stoppage time is not that higher value to decrease the availability at higher speed. Again we know that the ratio between target production and actual production expressed as a percentage is called performance percentage. At higher speed in a specified time more production is possible than at lower speed. For this reason the performance percentage has increased. Finally we can see that as a product of availability percentage, performance percentage and quality percentage the OEE has trend to increase with knitting machine speed.

In the graph increase rate of OEE is less at the speed 42 R.P.M. because at this R.P.M. the availability of the knitting machine is the lowest. It is due to the increased total stoppage time than at the speed 40 R.P.M.

2. Availability of knitting machine at different speed (R.P.M.): If we plot the availability against the machine speed (R.P.M.) we obtain the following graph shown in figure 4.2. We can see that availability has decreased at higher speed due to increase in total stoppage time. But at 44 R.P.M. the trend is opposite. At this speed, less number of set-off occurred which occupies 5 minutes each to repair. Due to higher tension caused by the higher speed of knitting machine the yarns have fewer tendencies to skip from needle hook. For this reason the set–off has occurred less number of times.

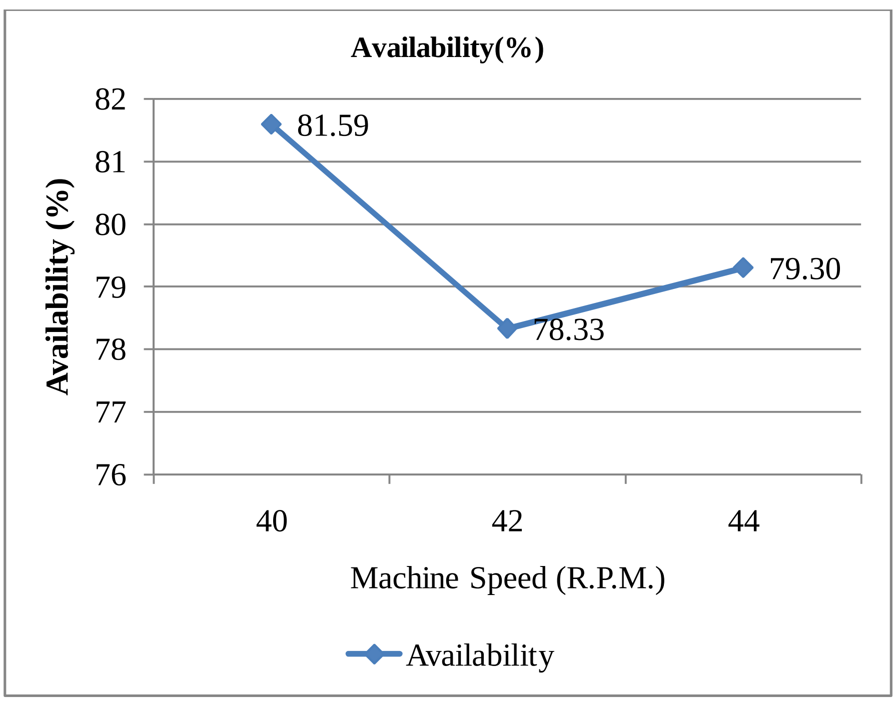


Figure 4.2: Availability (%) of knitting machine at different speed (R.P.M.)

From the graph we can see that availability is highest amount when the knitting machine speed is 40 R.P.M. It has decreased when the knitting machine speed is 42 R.P.M. Finally, at 44 R.P.M. availability has increased but it is less than 40 R.P.M.

We know that the availability percentage is the ratio between operating time and loading time expressed as a percentage. When the knitting machine starts to run at higher speed the operating time has decreased due to different causes of stoppages has increased. But the loading time remained same for knitting machine during running at different speeds.

3. Performance of knitting machine at different speed (R.P.M.): If we plot the performance against the machine speed (R.P.M.) we obtain the following graph:

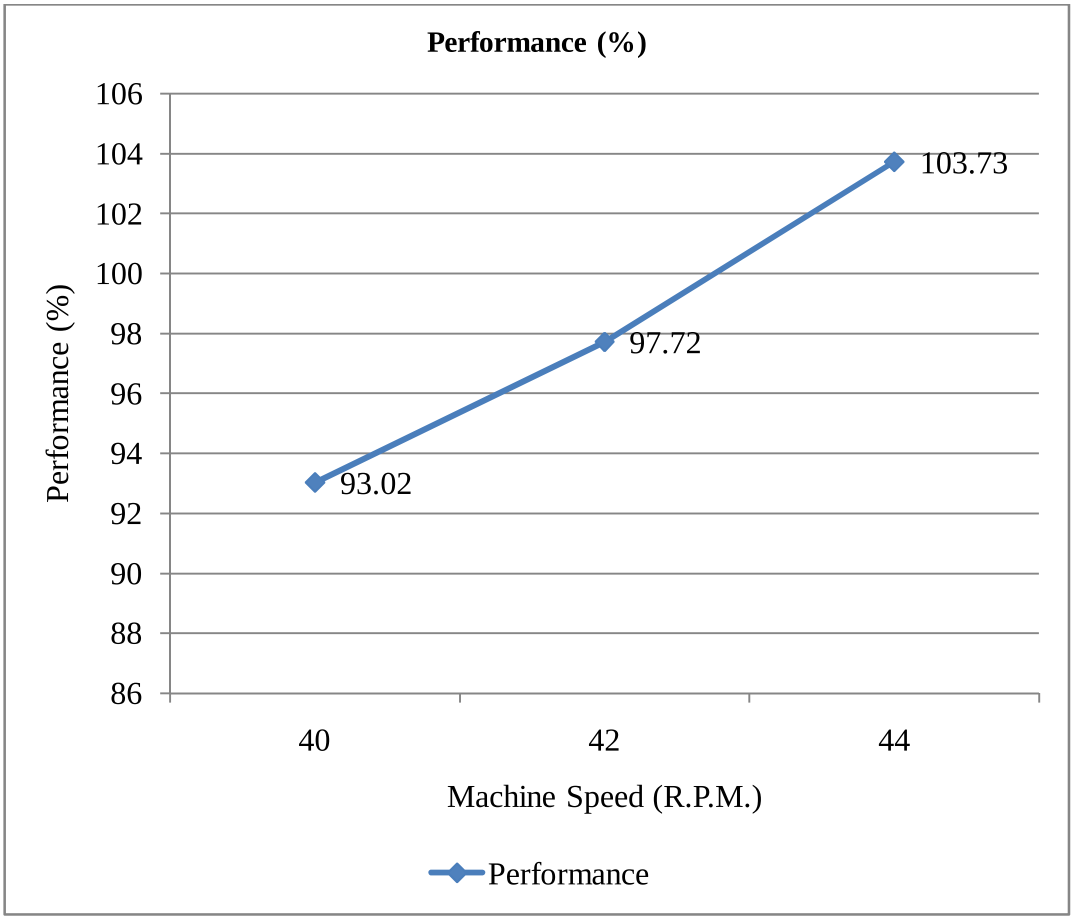


Figure 4.3: Performance (%) of knitting machine at different speed (R.P.M.)

We can see from graph that when the knitting machine speed (R.P.M.) has increased, the performance of the knitting machine also has increased.

We know that performance percentage is the ratio between actual production and target production expressed as a percentage. The performance of knitting machine has increased with increased speed because more fabric can be produced at higher speed than at lower speed at a specified time. For this reason the actual production is higher at higher speed than at lower speed This results in higher performance percentages at higher speed..

4. Rate of Quality Product of knitting machine at different speed (R.P.M.): If we plot the quality against the machine speed (R.P.M.) we obtain the following graph:

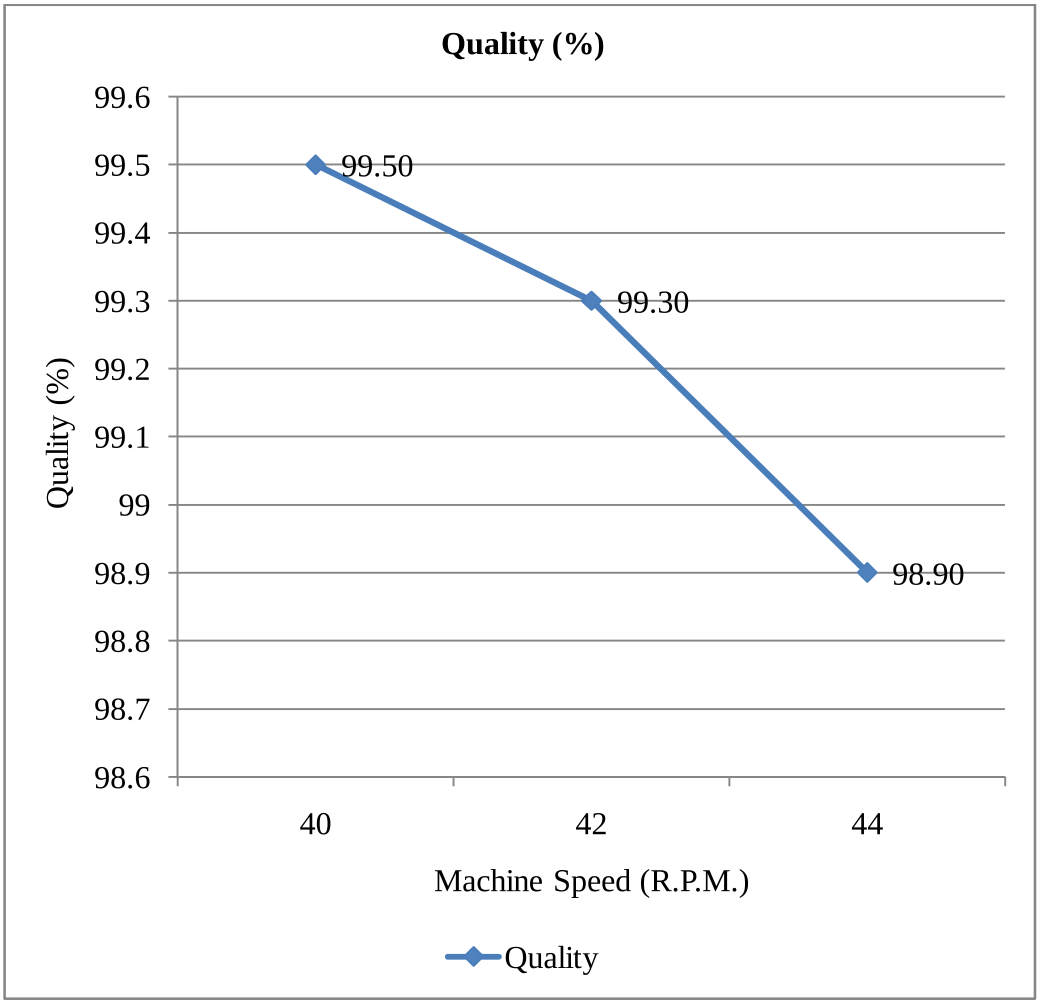


Figure 4.4: Quality (%) of knitting machine at different speed (R.P.M.)

We can see from graph that when the knitting machine speed (R.P.M.) has increased, the quality of the knitting machine has decreased.

We know that the quality percentage is the ratio between the good out-put and actual out-put expressed as a percentage. We can see when the knitting machine speed was increased the quality percentage was decreased. Because at higher speed the yarn was broken more frequently than at lower speed. Again at higher speed the needle started to break. This caused needle marks on fabric. Yarn breakages and needle breakages caused faults in fabric. For this reason the amount of defective fabric increased. Finally it has caused to quality percentage to decrease.

5. Defect amount (kgs): If we plot quality against machine speed (R.P.M.) we obtain the following graph:

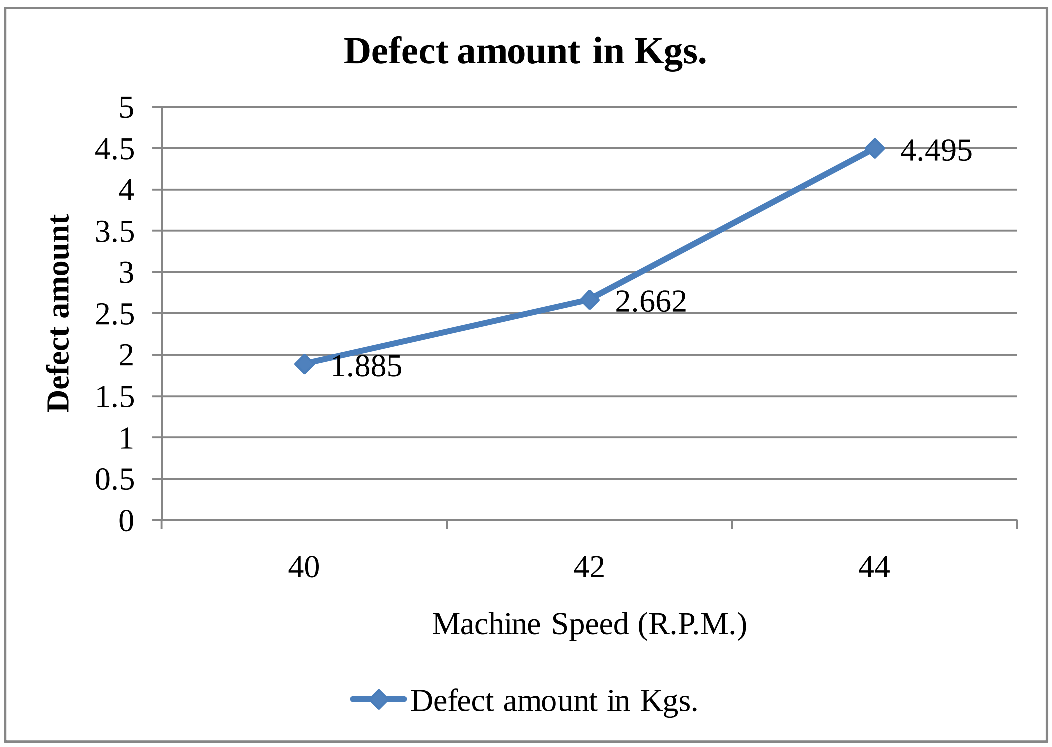


Figure 4.5: Defect amount of knitting machine at different speed (R.P.M.)

We can see from graph that when the knitting machine speed (R.P.M.) has increased, the defect amount of the knitting machine has decreased.

We can conclude that due to more yarn breakages and needle breakage the defect amount of fabric has increased with the increase of machine speed (R.P.M.).

6. Work load of knitting machine operator: From table the different works of knitting machine operator has been summarized:

Table 4.22: Different work load of knitting machine operator at different machine speed (R.P.M.)

R.P.M.	Yarn Breakage (min)	Set-off (min)	Machine Cleaning & Roll Cutting (min)	Others repairing (min)	Total Repairing Time (min)
40	60	43	129	33	265
42	55	48	130	79	312
44	79	31	129	59	298

If we plot total repairing time (min) against the knitting machine speed, we obtain the following graph:

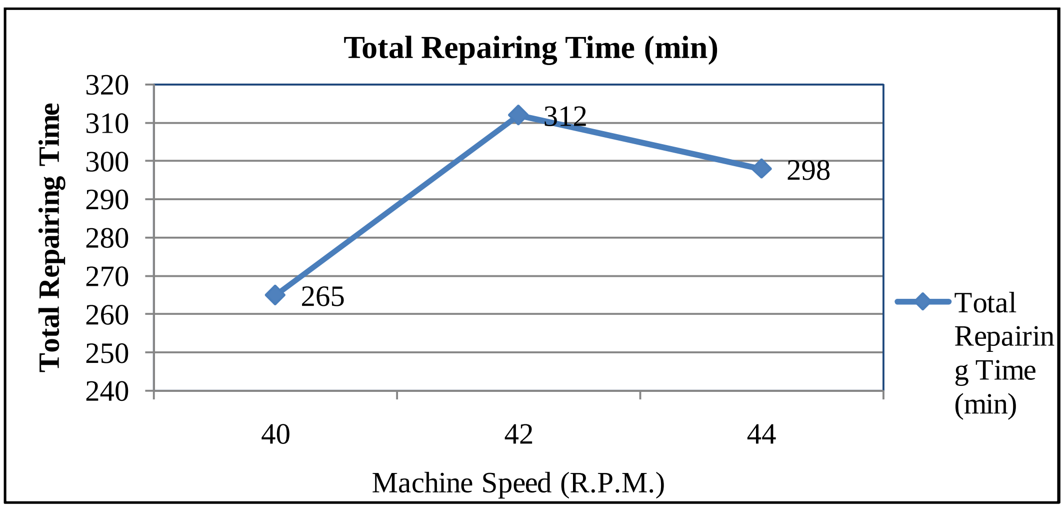


Figure 4.6: Total repairing time of knitting machine at different speed (R.P.M.)

We can see from graph that work load of knitting machine operator is lowest at 40 R.P.M. (265 minutes). It has increased at 42 R.P.M. (312 minutes). Finally, at 44 R.P.M. it has decreased (298 minutes) but it still remained more than at 40 R.P.M.

Due to more yarn breakage and more needle breakage the total repairing time of knitting machine operator has increased with increase of knitting machine speed.

7. Yarn breakage: If we plot total repairing time of yarn breakage (min) in Y axis and the knitting machine speed in X axis, we obtain the following graph:

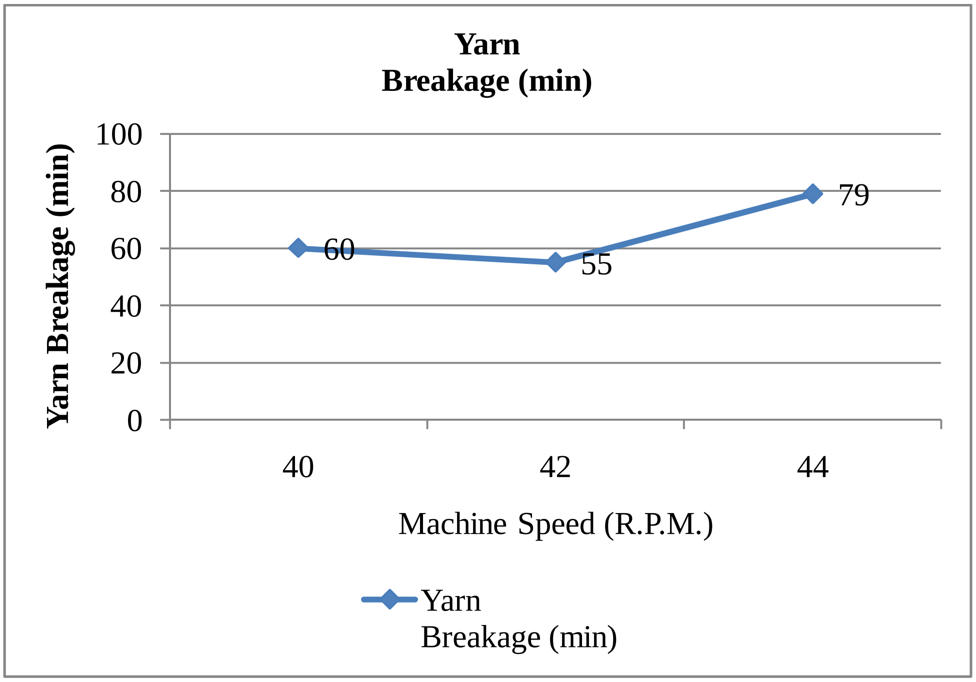


Figure 4.7: Yarn breakage (min) of knitting machine at different speed (R.P.M.)

We can see from graph that as the knitting machine speed increased, the occurrence of yarn breakage (min) also has increased.

The yarn breakage increased at higher speed because at higher speed yarn tension increases. Also the abrasion between knitting machine parts, especially with guides and needles increases as the speed is increased.

But at the speed 42 R.P.M. it exhibits an opposite trend. It is showing that the yarn breakages has decreased at 42 R.P.M. than the yarn breakages at 40 R.P.M. The tension on yarn has obviously increased but yarn breakage has decreased. It is due to the inertia of yarn and needle at higher speed. The passing of the yarn through the guides and tensioners becomes more even. This minimizes the affect of the increased tension and minimizes the number of yarn breakages.

Again at 44 R.P.M., higher speed of machine the yarn breakage has increased due to increased tension. Here the inertia of needle and yarn is not sufficient enough to overcome the increased yarn tension

8. Set-off: If we plot set off repairing time (min) in Y axis and the knitting machine speed in X axis, we obtain the following graph shown in figure:

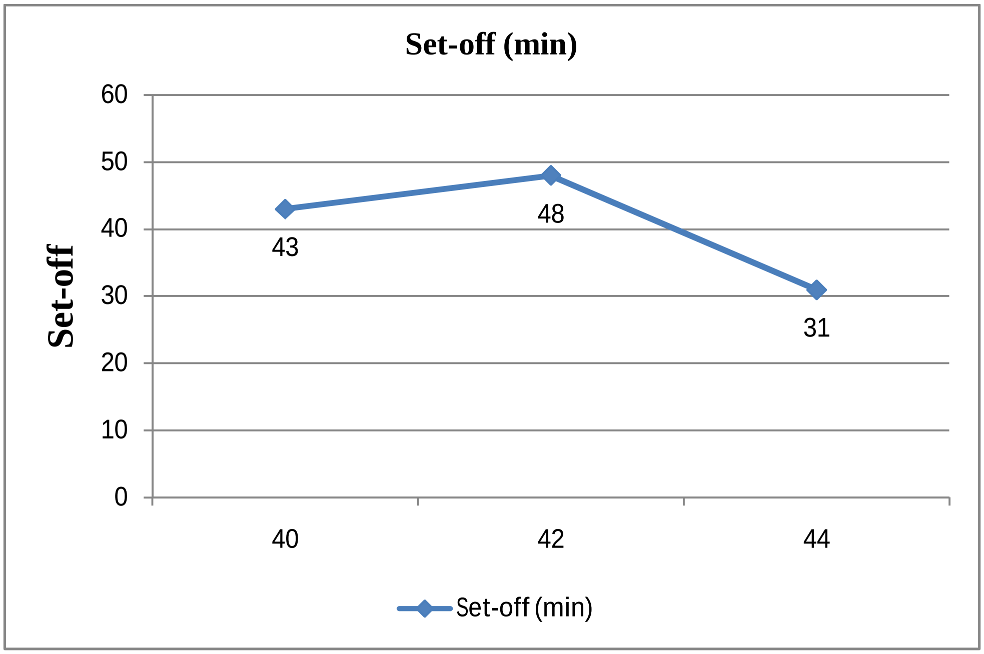


Figure 4.8: Set off (min) of knitting machine at different speed (R.P.M.)

Accumulation of fiber-fly on needle hook is the main cause of set-off. Set-off occurs when the needle releases the old loop but can not catch the new yarn due to clogging of needle hooks with fiber-fly. Again the if the tension in yarn is not correct then the set-off will occur. We can see from graph that as the knitting machine speed increased from 40 R.P.M. to 42 R.P.M., the occurrence of set-off has also increased. Again when the speed was increased to 44 R.P.M. the set off (min) has become less.

Set-off decreased at higher speed because the acceleration of needle and yarn becomes even at higher speed. The yarn is more evenly taken by the needles at same rate.

9. Machine cleaning and roll cutting time: If we plot machine cleaning & roll cutting (min) in Y axis and the knitting machine speed in X axis, we obtain the following graph shown in figure:

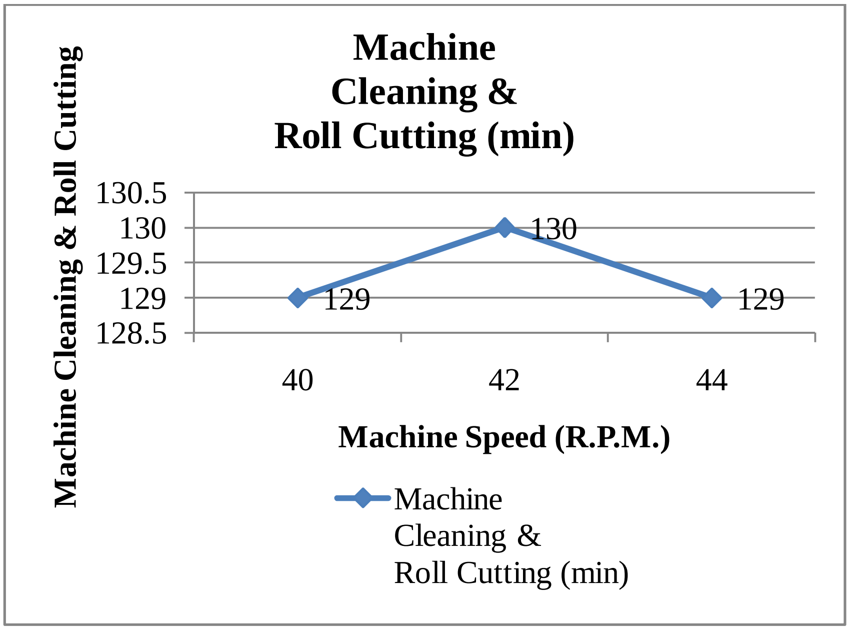


Figure 4.9: Machine cleaning & roll cutting (min) of knitting machine at different speed (R.P.M.)

From figure we can see that the machine cleaning & roll cutting time is maximum when the machine is running at 42 R.P.M. At 40 and 44 R.P.M. the time is equal to each other. Bur from table we can see that the values are almost equal to each other at three different speeds.

10. Other repairing time (min): In other repairing time the following are included: yarn joining, replacement of broken needle etc. If we plot machine others repairing (min) in Y axis and the knitting machine speed in X axis, we obtain the following graph shown in figure:

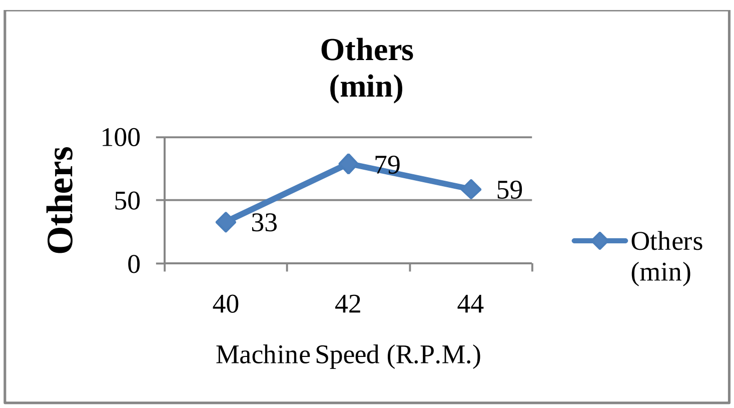


Figure 4.10: Other repairing (min) of knitting machine at different speed (R.P.M.)

We can see from graph others repairing time is highest when the machine is running at 42 R.P.M. At 40 R.P.M. the value is lowest. The value of other repairing time at 44 R.P.M. is between the values that have been observed at 40 and 42 R.P.M.

Other repairing time like changing broken needles has increased a lot at higher speed. Because at higher knitting machine speed, the friction between the needles and needle cam system increases a lot. It is mentionable that there is occurrence of breaking needle at each speed except at 40 R.P.M.

4.3.2 Analysis of Overall Equipment Efficiency (O.E.E.) varying number of feeders:

1. OEE of knitting machine with different no. of feeders: If we draw a histogram taking OEE at the Y axis we can see that knitting machine with 72 feeders showing more OEE than the 75 feeders knitting machine.

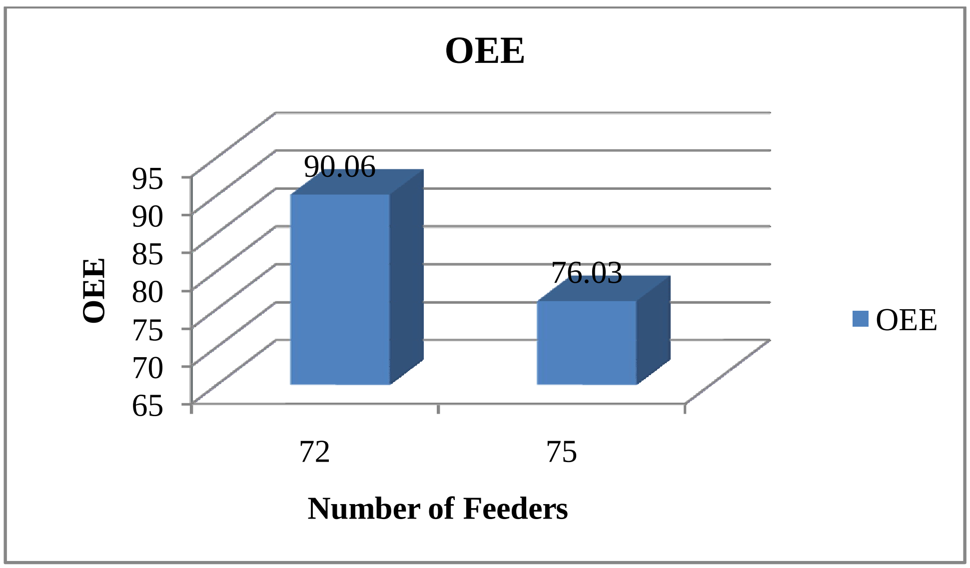


Figure 4.11: OEE of knitting machine with different number of feeders.

2. Availability of knitting machine with different no. of feeders: If we draw a histogram taking availability of the two machines with different no. of feeders, we can see that 72 feeder knitting machine showing more availability than 75 feeder knitting machine.

We know that the availability is the ratio between the loading time and operating time, expressed as a percentage. We can see that the availability of knitting machine with less number of feeders is high as its stoppage time is less. Knitting Machine with higher number of feeders feed higher number of yarns to the machine for this reason the possibility of breaking yarn and set-off increases. The machine had to stop more frequently to repair these faults. It is mentionable that both the machines had the same specified loading time.

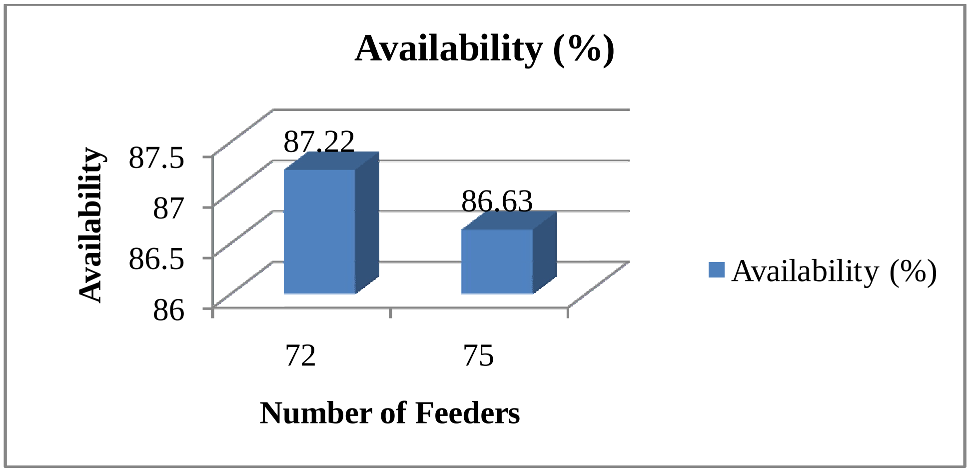


Figure 4.12: Availability (%) of knitting machine with different number of feeders.

3. Performance (%) of knitting machine with different no. of feeders: If we draw histogram for performance (%) of the two machines, we can see that 72 feeder machine showing more value of performance than the 75 feeder machine.

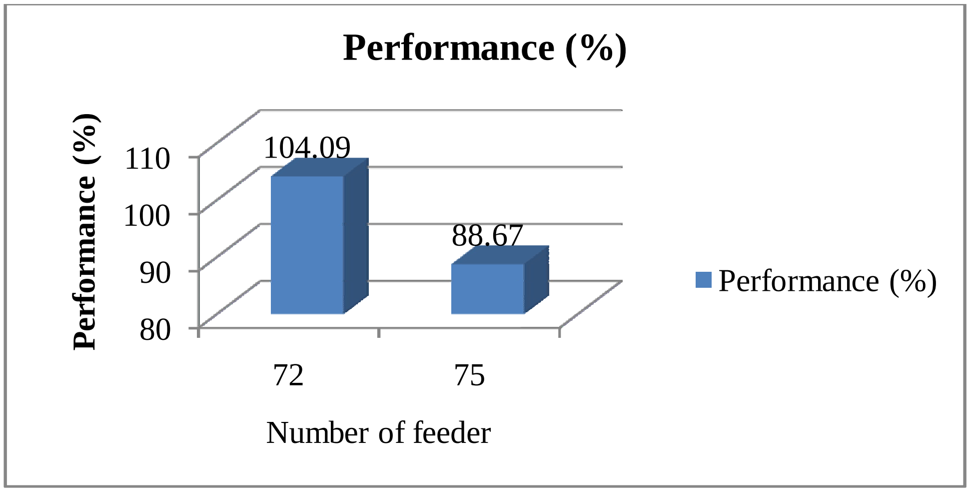


Figure 4.13: Performance (%) of knitting machine with different number of feeders.

We know that the performance percentage is the ration between the target production and actual production, expressed as a percentage. The performance percentage of knitting machine with 72 feeders' machine has higher value as it has less stoppage time than the machine with 75 feeders. This increases the operating time for knitting machine with 72 feeders.

4. Quality (%) of knitting machine with different no. of feeders: If we draw histogram for quality (%) of the two machines, we can see that 72 feeder machine showing more value of quality (%) than the 75 feeder machine.

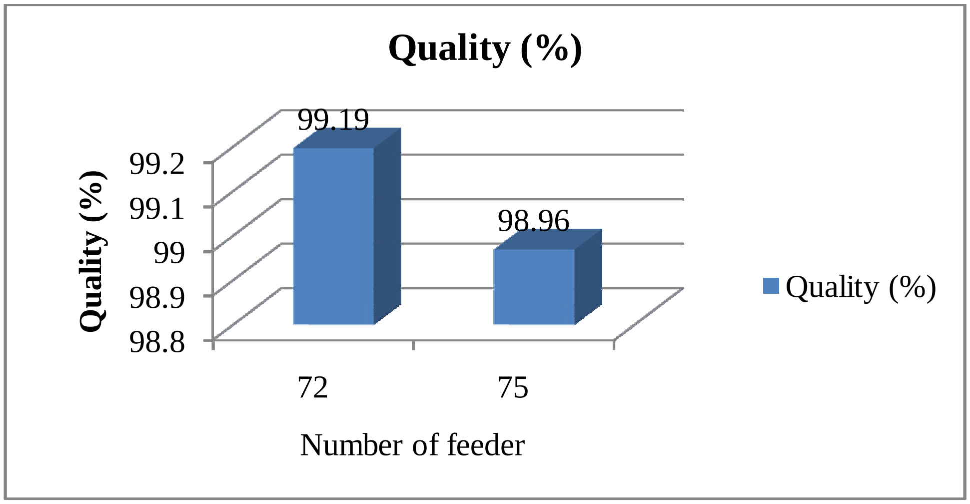


Figure 4.14: Quality (%) of knitting machine with different number of feeders.

We know that the quality percentage is the ratio between the good output with actual output. The quality percentage of knitting machine with higher number of feeder is high as more yarn breakage and set-off occurs in machine due to more number of feeders. These stoppages cause defects in fabric. For this reason quality percentage decreases. Due to the increased number of yarn breakage and set-off the defect amount of produced fabric has increased in 75 feeders knitting machine. For this reason the quality percentage has decreased.

Work load of knitting machine operator: From table the different works of knitting machine operator has been summarized:

Table 4.22: Different work load of knitting machine operator at machines of different number of feeders.

Type of Machine	Yarn Breakage (min)	Set-off (min)	M/C Cleaning & Roll Cutting (min)	Others (min)
72 feeder Machine	22	9	142	11
75 feeder Machine	25	13	101	53.5

5. Yarn breakage of knitting machine with different no. of feeders: If we draw histogram for yarn breakage (min) of the two machines, we can see that 75 feeder machine showing more value of yarn breakage (min) than the 72 feeder machine.

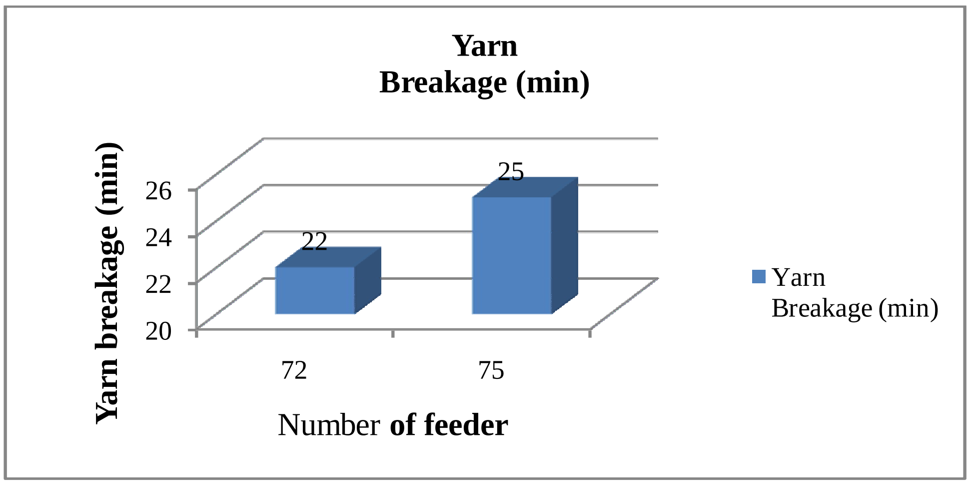


Figure 4.15: Yarn breakage (min) of knitting machine with different number of feeders.

The increased number of feeder increases the possibility of yarn break higher. For this reason we can see that more number of yarns has broken in machine with higher number of feeders.

6. Set-off (min) of knitting machine with different no. of feeders: If we draw histogram for set-off (min) of the two machines, we can see that 75 feeder machine showing more value of set-off (min) than the 72 feeder machine.

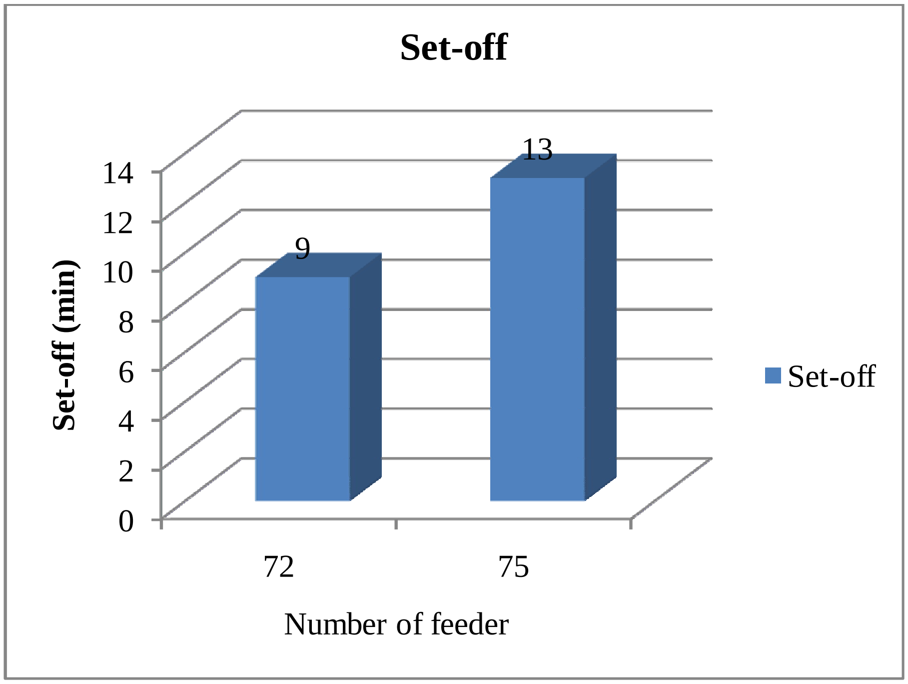


Figure 4.16: Set-off (min) of knitting machine with different number of feeders.

With increased number of feeders the possibility of set-off increases. For this reason more set-off occurred in the knitting machine with higher number of feeders.

7. Machine cleaning and roll cutting (min) of knitting machine with different no. of feeders:

If we draw histogram for machine cleaning and roll cutting (min) of the two machines, we can see that 72 feeder machine showing more value of time (min) than the 75 feeder machine. This is due to the fact that increased number of feeders shed more fiber fly in the knitting machine. This requires more time to clean the machine.

We can see that in 72 feeder machine, out-put is 286 kgs while in 75 feeder machine it is 252 kgs. Fabric roll is cut after almost 20 kgs of fabric has been produced. 72 feeder machine produces 34 kgs more fabric than 75 feeder knitting machine. This means it has been stopped two times more to cut fabric roll than 75 feeder machine. For this reason the 72 feeder machine was stopped two times more than 72 feeder machine. This includes additional 30 minutes to cut two more rolls. To cut a fabric roll and to clean the machine it required 30 minutes more stoppage time in 72 feeders machine.

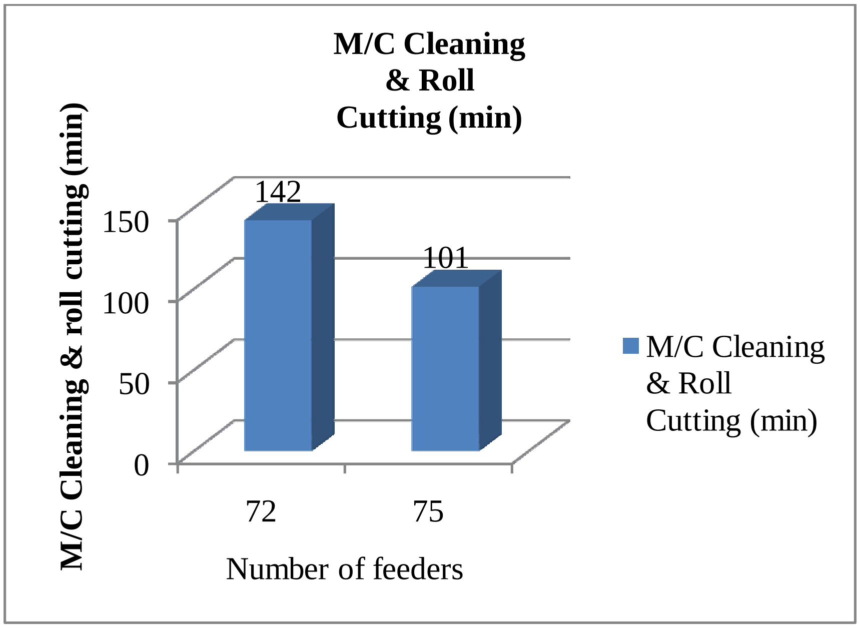


Figure 4.17: Machine cleaning & roll cutting (min) for knitting machines with different number of feeders.

8. Others repairing (min) of knitting machines with different number of feeders: If we draw histogram for others repairing (min) of the two machines, we can see that 75 feeder machine showing much more value of time (min) than the 72 feeder machine.

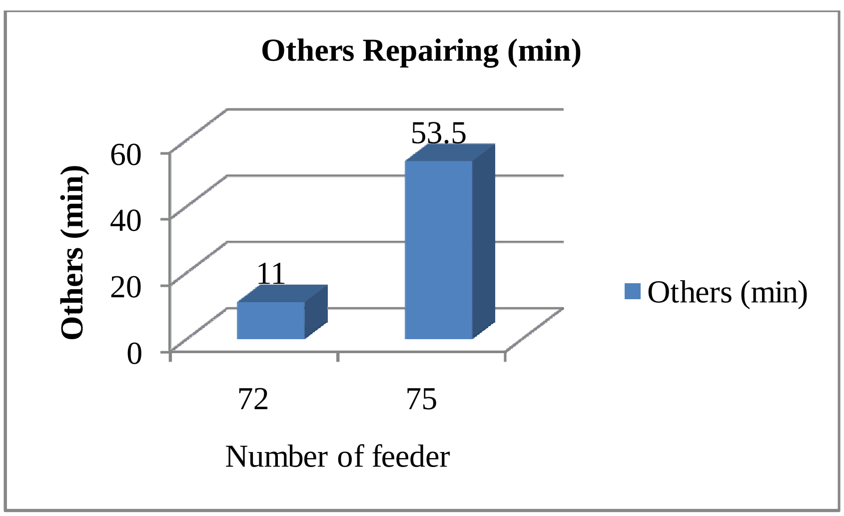


Figure 4.18: Others repairing (min) for knitting machines with different number of feeders.

4.3.3 Analysis of Overall Equipment Efficiency (O.E.E.) varying the yarn type

1. OEE of knitting machine varying the yarn type at different speed (R.P.M.): If we plot the OEE at different type of yarn running with different R.P.M. we obtain the following graph:

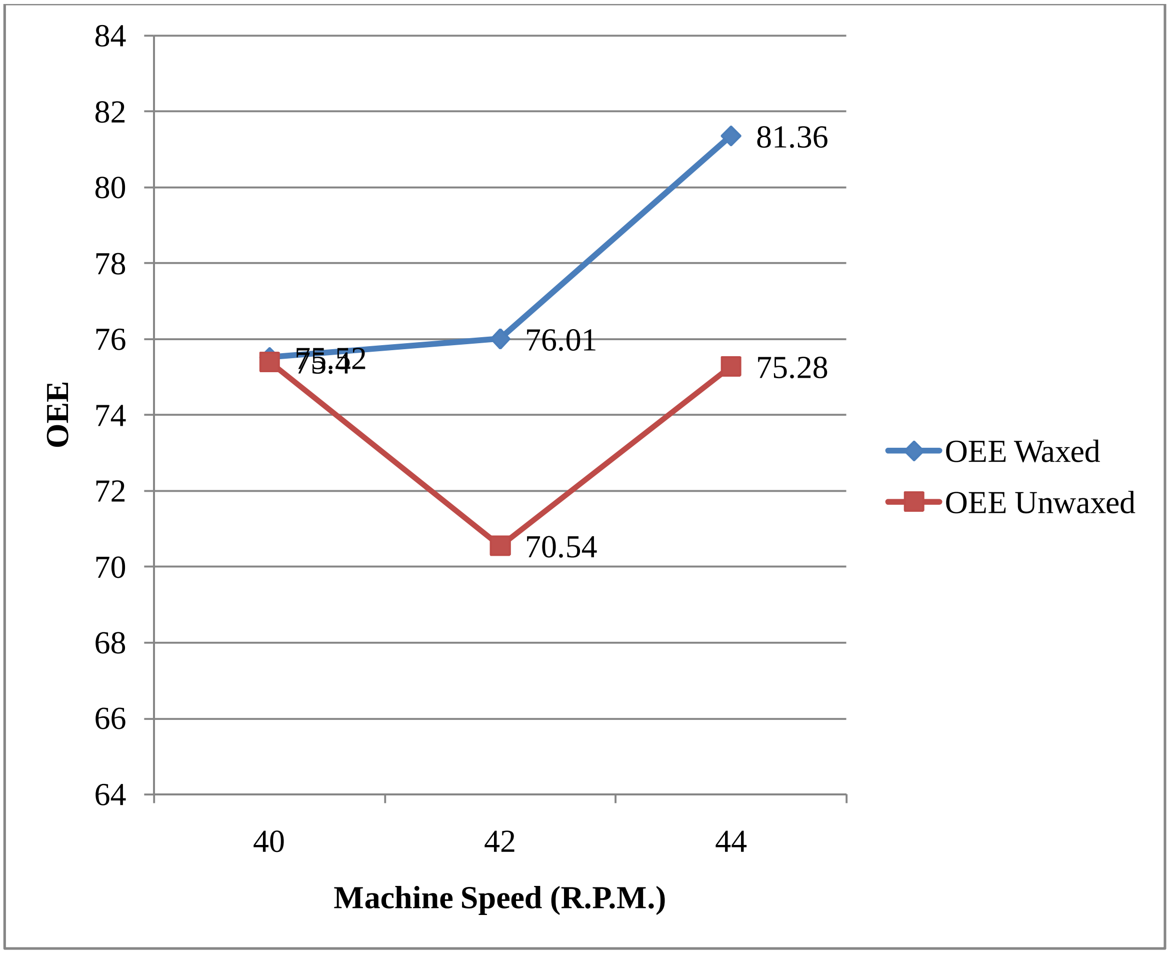


Figure 4.19: OEE of knitting machine at different speed with different yarn types

We can see that OEE of the knitting machine running with un-waxed yarn is always below the OEE of the knitting machine running with waxed yarn.

The knitting machine running with un-waxed yarn yields less OEE because the availability%, performance% and quality % becomes less due to more stoppage time and more amount of defective fabric production.

2. Availability of knitting machine at different speed (R.P.M.): If we plot the availability (%) against the machine speed (R.P.M.) with different types of yarn we obtain the following graph:

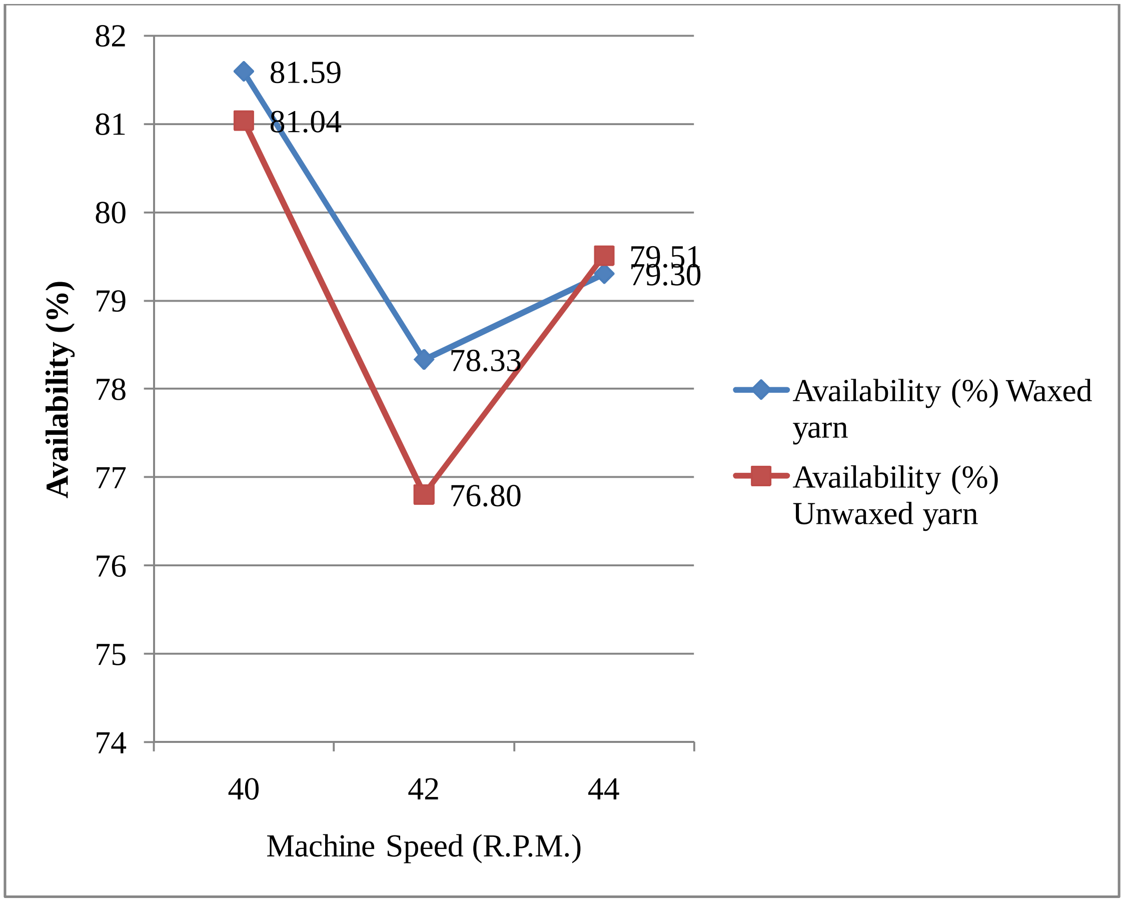


Figure 4.20: Availability (%) of knitting machine at different speed (R.P.M.) with different yarn types.

We know that the availability percentage is the ratio between loading time and operating time, expressed as a percentage. We can see that availability of knitting machine running with un-waxed yarn is always lower than the knitting machine running with waxed yarn. This due to more stoppage time of knitting machine running with un-waxed yarn. During knitting with un-waxed yarn the number of yarn breaks increased due to increase in friction with needle and other machine parts.

3. Performance (%) of knitting machine at different speed (R.P.M.): If we plot the performance (%) against the machine speed (R.P.M.) running with waxed and unwaxed yarn we obtain the following graph:

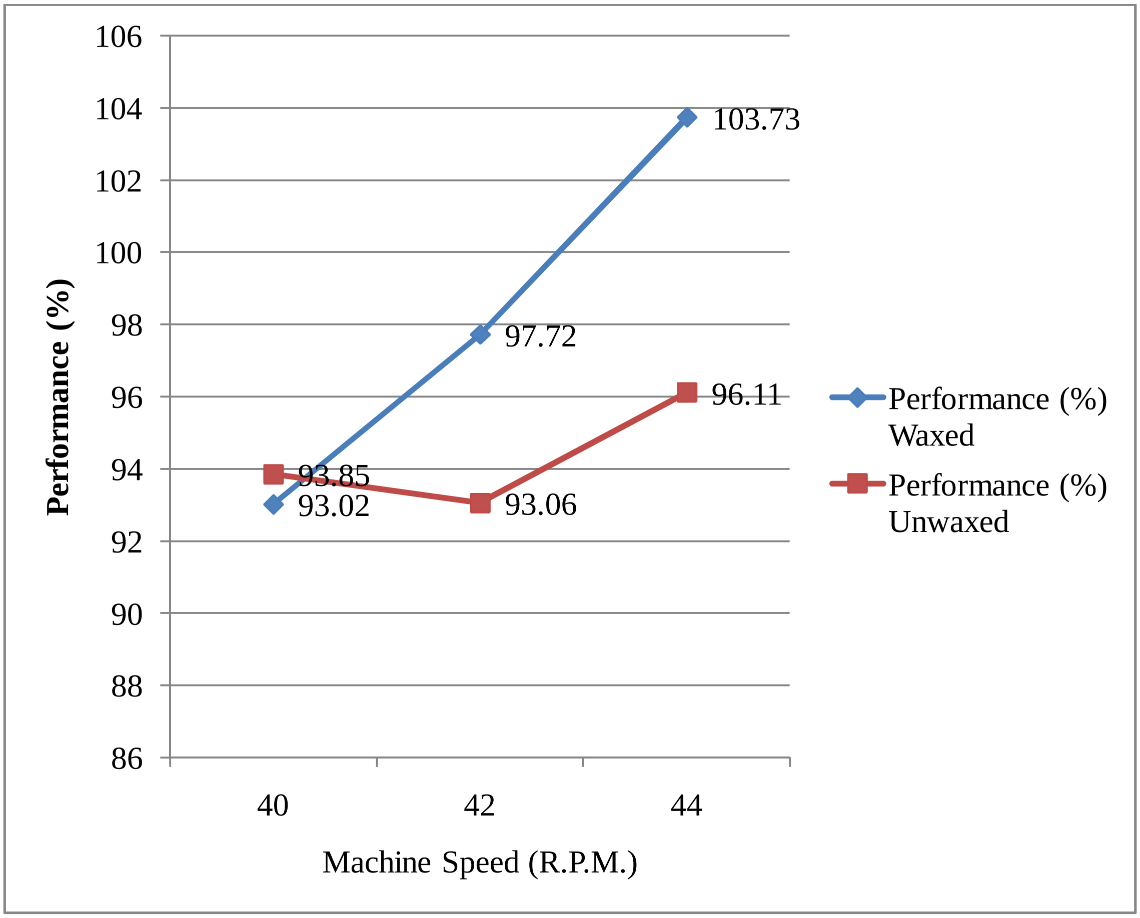


Figure 4.21: Performance (%) of knitting machine at different speed (R.P.M.) with different yarn type.

We can see that performance (%) of the knitting machine running with waxed yarn is always higher than the knitting machine running with un-waxed yarn.

Performance % of knitting machine decreases due to more stoppage time for increased number of yarn breaks and more number of set-off. But we can see that at a lower speed of machine the OEE of knitting machine running with un-waxed yarn is higher. Because at lower speed the tension is low on yarn. Again number of set-off is same in waxed and un-waxed yarn. And number of yarn breaks are almost same. But it take more time to repair set-off .

4. Rate of Quality Product of knitting machine at different speed (R.P.M.): If we plot the quality (%) against the knitting machine speed (R.P.M.) running with different type of yarn, we obtain the following graph:

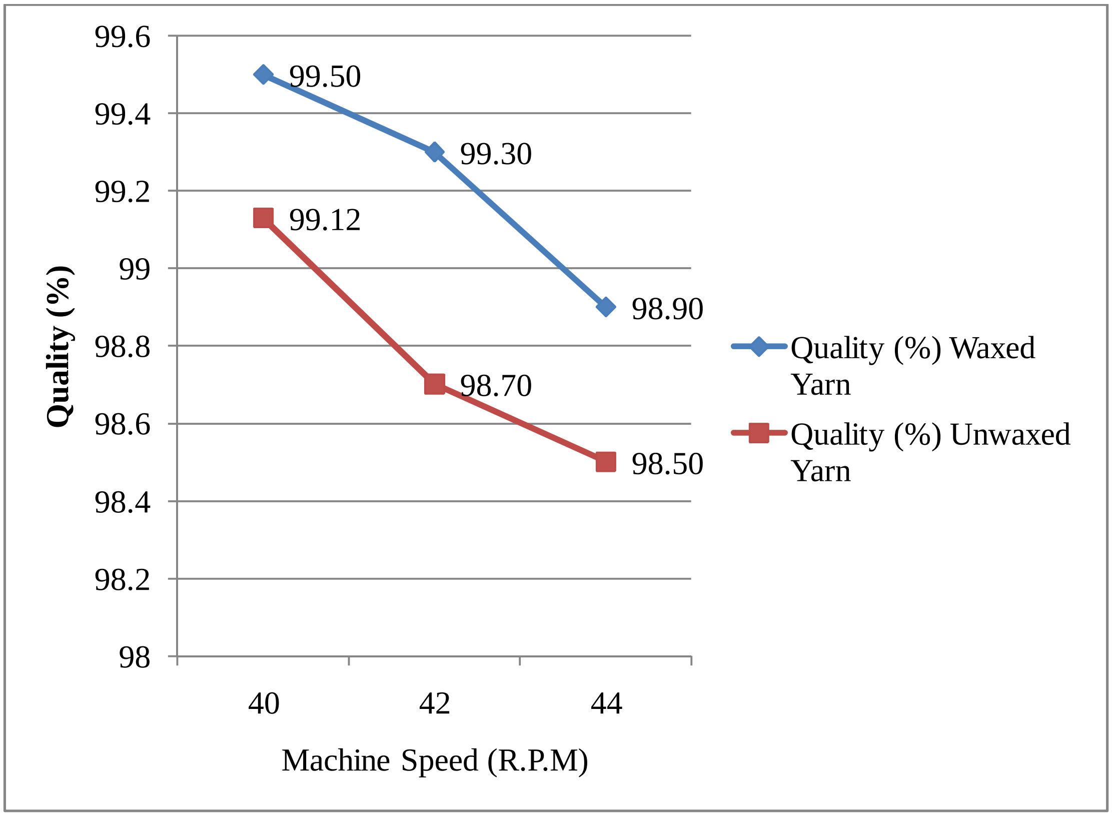


Figure 4.22: Quality (%) of knitting machine at different speed (R.P.M.) with different yarn types.

We can see from graph that the quality (%) is higher in the knitting machine running with the waxed yarn than the knitting machine running with un-waxed yarn.

We know that the quality % is the ratio between good output and actual output expressed as a percentage. Knitting machine running with un-waxed yarn faces more yarn breakage and set-off which adds defects on fabric. Due to increased amount of defective fabric the quality percentage decreases. Again with higher speed, the amount of defective fabric increases more due more number of yarn breakages.

5. Yarn breaks:

Table 4.23 No. of yarn breaks in knitting machine running with different types of yarn.

R.P.M.	No. of yarn breaks in Waxed	No. of yarn breaks in un-waxed
40	60	52
42	55	63
44	79	58

If we plot the values of Table 4.23 in graph, we get a comparative picture of no. of yarn breaks in knitting machine using waxed and un-waxed yarn.

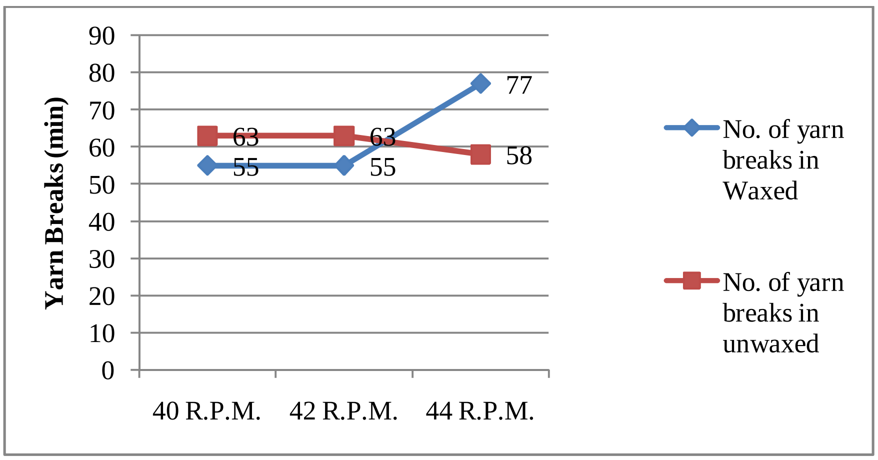


Figure 4.23: No. of yarn breaks in knitting machine running different R.P.M. with waxed and un-waxed yarn.

From data we can see from graph that in un-waxed yarn the no. of yarn breaks remained almost the same. But in waxed yarn the no. of breaks increased with the increase of R.P.M.

Un-waxed yarn is less slippery than waxed yarn. For this reason it faces more abrasive action with needle, different guides and tensioners. Due to this reason they break more than the waxed yarn. At higher speed the abrasive action increases more. For this reason the yarn breakage at higher speed in un-waxed yarn increased a lot.

6. Set-off:

Table 4.24: No. of set-off in knitting machine running with different R.P.M. with different types of yarn.

R.P.M.	No. of set-off in waxed yarn	No. of set-off in un-waxed yarn
40	6	6
42	7	13
44	14	14

If we plot the values of Table 4.24 in graph, we get a comparative picture of no. of set-off in knitting machine using waxed and unwaxed yarn in Figure 4.24.

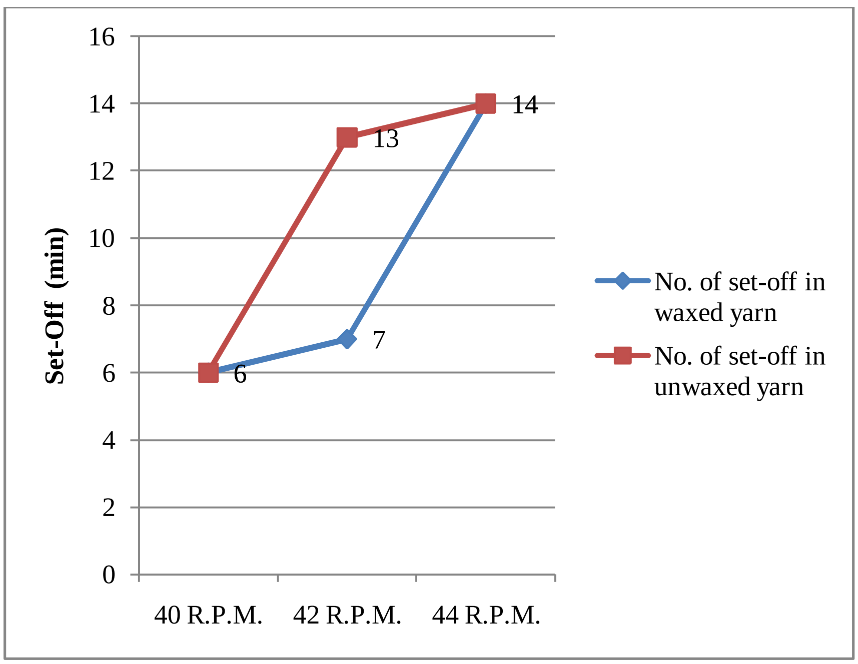


Figure 4.24: No. of set-off in knitting machine running with different R.P.M. with waxed and un-waxed yarn.

No. of set-off increased when we used un-waxed yarn in place of waxed yarn. It increased with the increase of R.P.M.

7. Machine cleaning time (min):

Table 4.25: Machine cleaning (min) in knitting machine running with different R.P.M. with different types of yarn.

R.P.M.	M/C cleaning in mins for waxed yarn	M/C cleaning in mins for un-waxed yarn
40	129	139
42	130	130
44	129	129

If we plot the values of Table 4.25 in graph, we get a comparative picture of machine cleaning (min) in knitting machine using waxed and unwaxed yarn in Figure 4.25.

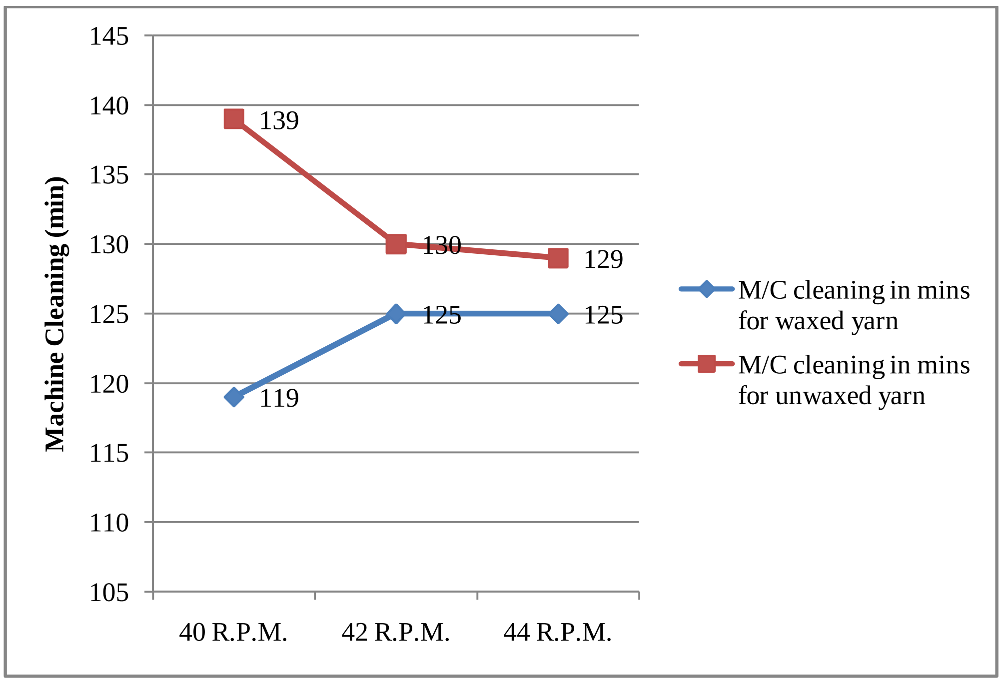


Figure 4.25: Machine cleaning time (min) knitting machine running with different R.P.M. with waxed and un-waxed yarn.

Machine cleaning time increased when we used un-waxed yarn in knitting production. The yarn number of breakage increased in un-waxed yarn because friction increased between yarn and different machine parts including needle. Again the difference of machine cleaning time has decreased at the higher speed during running with waxed and un-waxed yarns. Because a running machine parts and needle running at a higher speeds gathers less fiber-fly in hook. So, it takes less time to clean the machine.

8. Maintenance time (min):

Table 4.26: Maintenance time (min) in knitting machine running with different R.P.M. with different types of yarn.

R.P.M.	Machine maintenance in mins for waxed yarn	Machine maintenance in mins for unwaxed yarn
40	18	34
42	79	73
44	59	89

If we plot the values of Table 4.26 in graph, we get a comparative picture of maintenance time (min) in knitting machine using waxed and unwaxed yarn in Figure 4.25.

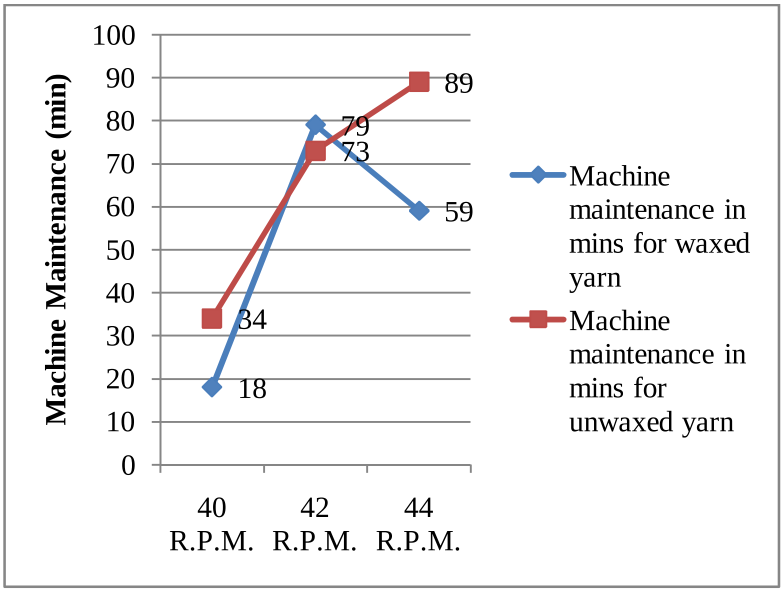


Figure 4.26: Maintenance time (min) in knitting machine running with different R.P.M. with different types of yarn.

Maintenance time increased when we used un-waxed yarn in place of waxed yarn.

9. Output (kgs):

Table 4.27: Out-put in kgs in knitting machine running with different R.P.M. with waxed and unwaxed yarn.

R.P.M.	Output in kgs for waxed yarn	Output in kgs for unwaxed yarn
40	377.1	365.1
42	380.3	355.1
44	408.7	379.7

If we plot the values of Table 4.27 in graph, we get a comparative picture of output (kgs) in knitting machine using waxed and un-waxed yarn in Figure 4.27.

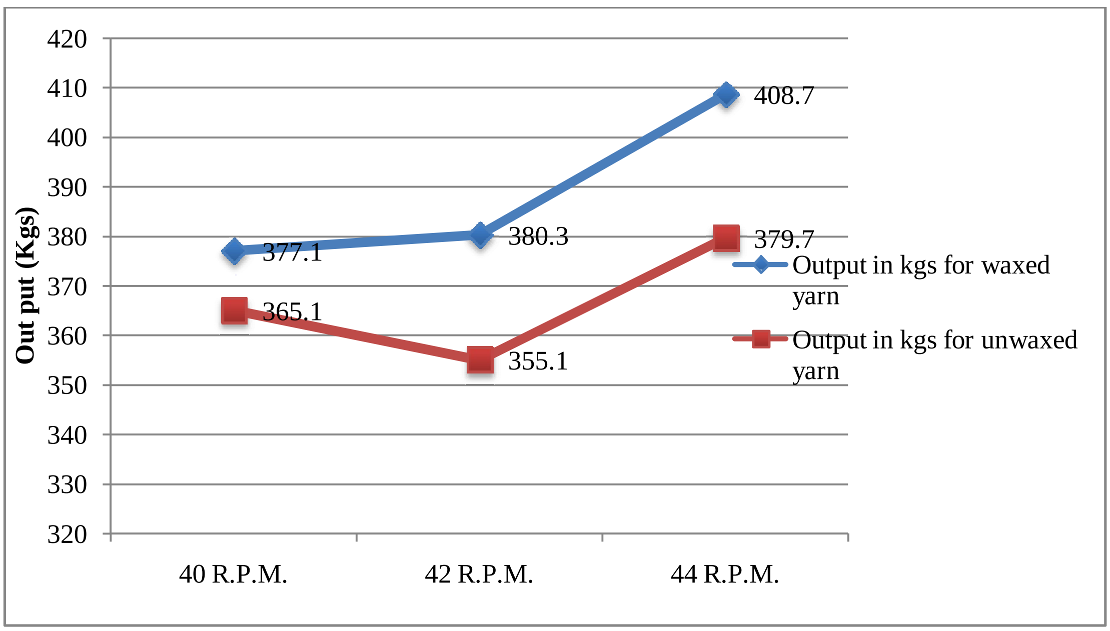


Figure 4.27: Out-put in kgs in knitting machine running with different R.P.M. with waxed and unwaxed yarn.

Output decreased when we used un-waxed yarn in place of waxed yarn. With the increase of R.P.M. the output also increased. Knitting machine running with un-waxed yarn had less availability. It had more stoppage time. It experienced more yarn breakages and set off. For this reason the output of the machine decreased. Again at lower R.P.M. the knitting machine running with un-waxed yarn had less number of yarn breakage and set-offs. For this reason the stoppage is less R.P.M. At these points the difference is less between the output of un-waxed and waxed yarn.

10. Defect amount:

Table 4.28: Defect amount in knitting machine running with different R.P.M. with different types of yarn.

R.P.M.	Defect amount in Kgs. (Waxed yarn)	Defect amount in Kgs. (unwaxed yarn)
40	1.885	3.29
42	2.662	4.61
44	4.495	5.69

If we plot the values of Table 4.28 in graph we get the relative picture in Figure 4.28 of defect amount knitting machine running with different R.P.M. with waxed and unwaxed yarn.

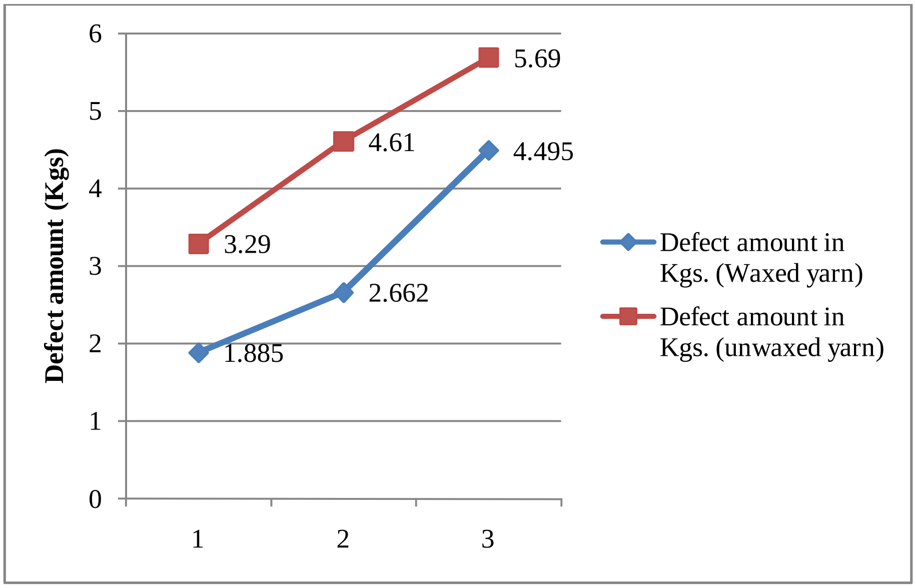


Figure 4.28: Defect amount in knitting machine running with different R.P.M. with different types of yarn.

Defect amount increased when we used un-waxed yarn with increased R.P.M. and knitting machine running with un-waxed yarn exhibit more defect amount than knitting machine running with waxed yarn.

Defect amount increased in knitting machine running with un-waxed yarn because un-waxed yarn faces more yarn breakage and set-offs which adds defects in fabric. Again at higher speed the rate of yarn breakage and set-off increases. For this reason we can see that defect amount increased in knitting machine running with un-waxed yarn at higher speed.

Chapter 5

Observations and Recommendation

5.1 Observations

5.1.1 Observations during varying the Knitting Machine Speed: If we increase the speed of knitting machine from 40 R.P.M. we faced the following problems:

When the knitting machine was running at speed 42 R.P.M.

1. The Overall Equipment Efficiency (OEE) increased at a very less amount (only 0.512%)

2. Defect amount increased to 0.777 kg.

3. Knitting needle was broken during knitting.

When the knitting machine was running at speed 44 R.P.M.

1. The Overall Equipment Efficiency (OEE) increased at a very significant amount. (6.126%)

2. Defect amount increased to 2.61 kgs.

3. No. of yarn breaks increased to 79 (i.e. increased by 40%) which increased the work of machine operator.

4. Knitting machine needle was broken more frequently than at the speed 42 R.P.M.

5.1.2 Observations during varying the number of feeders:

1. When the number of feeders increased the OEE of knitting machine decreased.

2. When the number of feeders increased the availability (%) of knitting machine decreased.

3. When the number of feeders increased the performance (%) of knitting machine decreased.

4. When the number of feeders increased the quality (%) of knitting machine decreased.

5. When the number of feeders has increased the yarn breakage of knitting machine also has increased.

6. When the number of feeders has increased set-off of knitting machine also has increased.

7. When the number of feeders has increased machine cleaning and roll cutting time of knitting machine has decreased.

8. When the number of feeders has increased other repairing or maintenance time (min) of knitting machine also has increased.

9. Knitters' Expectations:

Table 4.29: Knitters' expectations on Efficiency as the no. of feeder increases:

M/C #	Dia	Gauge	No of Feeders	Yarn Count	Stitch Length	R.P.M	Production / Day	Defect Amount	Calculated Production	Efficiency %
8	23	24	69	24	2.75	28	230	1 kg	326.46	70.45
9	24	24	72	24	2.75	28	240	1 kg	355.46	67.51
10	25	24	75	24	2.75	26	250	1 kg	358.15	69.80
11	28	24	84	24	2.75	26	280	1 kg	449.27	62.32
12	30	24	90	24	2.75	25	290	2 kg	495.91	58.47

Source: TEXEUROP (BD) Ltd.

From the Table 4.29 we can see that when no. of feeders increases the knitters expect a lower efficiency of knitting machine.

We can summarize that,

1. When the no. of feeders increased the OEE, Availability (%), Performance (%) and Quality (%) decreased.

2. When the no. of feeders increased the yarn breakage, set-off and maintenance time increased.

3. When the no. of feeders increased the machine cleaning time decreased which has less significance.

5.1.3 Observations during varying the yarn type:

1. We can see from graph that a higher value of Overall Equipment Efficiency is obtained by using waxed yarn than un-waxed yarn. It increased with the increase of R.P.M.

2. Availability (%) of knitting machine running with un-waxed yarn is always lower than the knitting machine running with waxed yarn.

3. Performance (%) of the knitting machine running with waxed yarn is always higher than the knitting machine running with un-waxed yarn.

4. The quality (%) is higher in the knitting machine running with the waxed yarn than the knitting machine running with un-waxed yarn.

5. At the same time in un-waxed yarn the no. of yarn breaks remained almost the same. But in waxed yarn the no. of breaks increased with the increase of R.P.M.

6. No. of set-off increased when we used un-waxed yarn in place of waxed yarn. It increased with the increase of R.P.M.

7. Machine cleaning time increased when we used un-waxed yarn in knitting production.

8. Maintenance time increased when we used un-waxed yarn in place of waxed yarn.

9. Output decreased when we used un-waxed yarn in place of waxed yarn. With the increase of R.P.M. the output also increased.

10. Defect amount increased when we used un-waxed yarn with increased R.P.M.

We can summarize that, by using waxed yarn,

1. We increase OEE, Availability (%) Performance (%) Quality (%), output (kgs)

2. We can decrease the yarn breaks, set-off, machine cleaning time and maintenance time.

5.2 Recommendations

5.2.1 Recommendations for Varying the Knitting Machine Speed:

From the above discussions we can conclude that 40 R.P.M. is the optimum speed though we get least amount of Overall Equipment Efficiency (O.E.E.), because:

1. There is least amount of defects. This means less wastage of yarn and utilities of knitting section.

2. There is least amount of yarn breaks. This means less work load on the knitting machine operator.

3. Needle started to break beyond this speed.

5.2.2 Recommendations for varying the number of feeders:

Our observations says that the less no. of feeder the more efficient the knitting machine will be.

But less no. of feeders means less production/hour. So, we have to make cam angle less steeper so that R.P.M. can be increased to overcome the production amount.

5.2.3 Recommendations for varying the type of yarn:

1. We observed that yarn breaks, set-off, Machine cleaning time and Maintenance time increased when un-waxed yarn was used in place of waxed yarn.

2. Output decreased and defect amount increased with un-waxed yarn when the knitting machine was running with higher R.P.M.

We can conclude that we cannot substitute un-waxed yarn with waxed yarn. Again if we have to use un-waxed yarn we have to run the knitting machine with reduce speed.

Conclusion:

From this thesis work it has found that the optimum speed of knitting machine for given stitch length and yarn is 40 R.P.M. Again it has been observed that the OEE of knitting machine can be increased if it has less number of feeders. But less number of feeders of knitting machine will yield less production. For this reason to overcome this speed of machine has to be increased. But for the existing knitting machine cam design there is a limit to increase the machine speed. So, it is required to find an optimum combination of machine speed (R.P.M.) and number of feeders to keep the output amount high.

Further study

Yarn quality affects the knitting machine availability percentage, performance percentage and quality percentage. Here it is mentionable that OEE will change if type of yarn changes. For example combed yarn has better quality in respect of strength and evenness than the carded yarn. Again yarn twist plays on the strength of yarn. Yarn with more twist exhibits more strength. For this reason the yarn will break less number of times. Yarn with weak and thin places breaks more rapidly than the yarn which has less thin and weak places. At higher speed of knitting machine yarn strength plays a good role for knitting. So, we can say that the OEE of knitting machine will change with the change of yarn quality. The yarn quality includes; type of yarn, count of yarn, T.P.I. of yarn, yarn strength etc. The author finds it very important to study the relation between OEE of knitting machine and yarn quality.

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