ADDIS ABABA UNIVERSITY

INSTITUTE OF TECHNOLOGY

SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING

MASTER’S THESIS

ON

DESIGN OF COTTON SPINNING MACHINE FOR MIDDLE TEXTILE INDUSTRIES

A thesis submitted to the school of Graduate studies of Addis Ababa University in partial fulfillment of the Degree of Masters of Science

In

Mechanical Engineering (Mechanical Design Stream)

By: Chalachew Setegne

Advisor: Dr.-Ing Tamirat Tesfaye

Oct, 2014

Declaration

I, the undersigned, declare that this thesis project report entitled **“DESIGN OF COTTON SPINNING MACHINE FOR MIDDLE TEXTILE INDUSTRIES”** is the result of my own research carried out under the supervision of Dr.-Ing Tamirat Tesfaye. It has not been presented as a thesis in any other and all sources of material used for this thesis are duly acknowledged.

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Chalachew Setegne Date

This is to certify that the above declaration made by the candidate is correct to the best of my acknowledge.

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Dr.-Ing. Tamirat Tesfaye Date

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ABSTRACT

Micro and Small Scale Enterprises (MSE's) are widely implementing and developing in all sectors in Ethiopia. When we see one of the major sectors in which MSE's are involved is in textile sector and when we observe the commonly used cotton spinning machines used by weavers organized in MSE's and in home to home is made of wood. It only spines on one take-up shaft from a supply of cotton and consumes large amount of man-work hours to get so many spun yarn. But, cotton spinning is the main operation in the production of clothes by micro and small scale owners. Therefore, it is important to improve the spinning system that can be operated by small and middle scale industry level. Understanding this reality, this thesis focuses on designing cotton spinning machine. In this thesis, theoretical background and development of spinning is discussed; different characteristics of yarn are studied and spinning systems with their economic ranges are explained. On the product planning stage, different mechanisms and components are compared and selected properly. Based on the selection a spinning machine that can spin cotton in to yarn similar to hand spun yarn is designed. The machine will be operated by motor; spools are feed to the machine manually.

Acknowledgments

I express my humility and utmost gratitude to God for his blessings in my life. Verily no success would have been achieved without his grace and mercy.

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Nomenclatures

C	centrifugal force
C_Y	yarn count,
D_R	ring diameter
D_T	total draft
H	balloon height
K	the yarn-lappet coefficient of friction
M	traveler mass
N	total number of possible comparison pairs.
N	total number of criteria
N_I	rotation speed of the twisting device used in spinning the yarn
N_M	number of spinning positions
N_s	spindle speed (rpm)
N_t	traveler speed (rpm)
P	yarn-traveler coefficient of friction
P_S	production per spindle
R_R	ring radius
t	level of twist
T_B	balloon tension
T_F	twist factor,
T_O	tensions in the balloon length at the lappet guide
T_R	tensions at the ring and traveler
T_S	spinning tension
T_W	winding tension
V_d	delivery speed
w_i	the weighting factor
θ and α	angles
ω	angular velocity of the traveler

CHAPTER ONE

INTRODUCTION

1.1 Background

Cheap and abundant supply of machine, which satisfies its functional requirements, is one of major factors for the development and progress of the developing countries like Ethiopia. Design and production of these machines are useful for improvement of the method of the work.

An over- whelming majority of Ethiopia population live in rural areas where electric energy is not available. From this fact machines which are operated by man power are more important and help in making the rural life more improved. Understanding this truth it is have tried to develop simple manually/motor operated yarn winding machine which can be applicable for micro and small scale industries particularly focusing on textile sector. The function of this winder is to wind fiber with a better speed and quantity by taking in to an account of a certain design consideration so as to satisfy the customers demand.

Based on Federal Micro and Small Enterprises Development Agency, industries are leveled as micro and small scale, middle scale and high level industries based on their capital, production capacity and Technology.

Micro and small scale Industry: is a business that is privately owned and operated, with a small number of employees (6 – 30 including owners' family) and relatively low volume of sales. Small businesses are normally privately owned corporations, partnerships, or sole proprietorships. Number of micro and small scale industries are graduated to Middle scale level including textile sectors.

A middle Scale Industry: usually one with 10 to 100 employees and capital of Birr 1,500,000 and above (the maximum value of capital and employment capacity in Ethiopia is not mentioned). They collectively employ more people than large companies, and usually have a less formal structure.

Cotton is one of the oldest cultivated fiber crops in Ethiopia. The low to mild altitude areas of our country Ethiopia are generally known to have an immense potential for the production of cotton subject to the availability of water. In terms of productivity, high yields are obtained in areas with altitude ranging up to an altitude of 1000 meters above sea level. Ethiopia has enormous potential for the production of cotton. Out of the total 2.6 million ha of land suitable for cotton production, 1.7 million ha or 65% is found in 38 high potential cotton producing areas and the remaining 0.9 million ha or 35% is in 75 medium potential districts. Despite this immense potential, Ethiopia currently produces only about 77,000 - 84,000 MT of raw/seed cotton annually from a total cotton area of 42,371 ha. Cotton and its products are now the major cash crops in Ethiopia. It offers considerable employment opportunity on farms, in textile factories and in the ginneries. But still the benefit we found from cotton and its products is least; it needs more work in cotton production and implementing textile industries from micro and small scale to higher level industries.

The development of MSE's in all sectors is instrumental for the growth of developing countries. Ethiopia one of the developing countries, has been given due attention to the development of MSE's since they contribute considerably to the development of the country basically providing employment opportunity to the whole cause by receiving the able support of governmental and nongovernmental organizations. Designing, popularization and transfer of prototypes of technologies/production equipments suitable for MSEs has been one of the major activities of the Federal Micro and small scale Enterprise Development Agency. Now MSEs are playing a significant role in reducing unemployment in both the Urban and rural areas of Ethiopia.

However due to technological resource limitations it is obviously predictable that most of MSE's face problems even to purchase and utilize machines that would help them to be productive in their activities. To address these scenarios it needs the contribution of each stakeholders involved in the sectors primarily focusing on technologies currently employed by them with a view to explore the possibilities of improving them.

When we see one of the major sectors in which MSE's are involved is in textile sector and when we observe the commonly used cotton spinning machines which converts cotton to yarn, used by weavers and in homes is made of wood. It only spines on one take-up shaft from a supply of cotton and consumes large amount of man-work hours to get so many spanned fiber. Also when we observe the commonly used yarn winding machines used by weavers is made of wood. It only winds on one take-up shaft from a supply of spool and consumes large amount of man-work hours to get on so many winds.

Understanding this reality, it is designed develop produce and test a yarn winding machine which can wind up to hundred spindles (hundred times improvement) at the same time. Also, designing and developing a spinning machine in a similar way to the winding machine is started. But, micro and small scale textile enterprises are now developing their capacity this will drive their interest to get more productive spinning and winding machines which can increase their production rate save their time and power.

Based on these the interested to develop further the spinning machines in a more productive and automated way is initiated. There for this thesis work focuses on designing a machine which can spin processed cotton to yarn. The machine will be operated by one motor; spools feed and unfed to and from their shafts manually; a person will control and facilitate the overall operation.

Generally there are many phases in the textile production process, and operators' duties depend on the product and type of machinery used. The process begins with the preparation of synthetic or natural fibers for spinning. Fibers are cleaned and aligned through processes called carding and combing. To prepare the fiber for spinning, very short fibers and foreign matter are removed, and the fibers are drawn into a substance called sliver. During this process, different types of fibers may be combined, to give products a desired texture, durability, or other characteristics. Operators constantly monitor their machines during this stage, checking the movement of the fiber, removing and replacing cans of sliver, repairing breaks in the sliver, and making minor repairs to the machinery. The full cans of sliver are then taken to the spinning area, where they are drawn and twisted onto bobbins to produce yarn. The produced yarn will be winded on spindle.

Finished yarn winded on the spindle is then taken to be woven, knitted, tufted, or bonded with heat or chemicals. Each of these processes creates a different type of textile product and requires a different type of machine. Woven fabrics are made on looms that interlace the yarn. Knit products, such as socks or women's hosiery, are produced by intermeshing loops of yarn. Carpeting is made through the tufting process, in which the loops of yarn are pushed through a backing material. Although the processes are now highly automated, these concepts have been used for many centuries to produce textile products. Once the yarn has been woven, knitted, or tufted, the resulting fabric is ready to be dyed and finished. Out of these textile production operations my thesis will only focus on only the spinning phases.

Micro and small scale enterprise operators (MSE's) are now implemented in Ethiopia widely. These operators are working and developing, even graduated to middle scale industry levels, as they work and develop further their interest will increase, they demand to get more advanced machines in quality and productivity. Also the capacity of cotton production in Ethiopia needs more advanced machines in abundance.

Therefore this project aimed to develop a middle scale industry level cotton spinning machine to fulfill the demand of different industries engaged in textile sectors.

1.2 Statement of the Problem

Cotton and textile production is one of development base of developing country like Ethiopia. Ethiopia has enormous potential for the production of cotton which can create high job opportunity and foreign currency. To reach at the maximum benefit of cotton and textile production in employment and gaining foreign currency it is obvious to widen and increase the quality quantity of cotton and textile products. To increase and widen these products, we should be able to move and utilize the huge amount of man power with technological support/ introduction of appropriate technology by establishing micro and small scale enterprises and middle scale industries especially in regional areas where most of the man power is available.

For these sectors appropriate technology machineries are required. Two of the main operations in textile production are cotton spinning and yarn winding.

But when we see different machines and mechanisms including spinning phase in different textile sectors of micro and small scale enterprise even those developed to middle scale industries are tiresome, time taking and less productive.

From this fact, the importance of developing a middle scale spinning machines effective in operation production rate, quality of product and saving the man power has no question. To accomplish the work and solve the problems it is required to study different parameters mechanisms and materials related with the spinning and winding machines. Then, designing, producing, testing, and disseminating the machine.

1.3 Objectives

1.3.1 Major objective

The **major objective** of this project is to design higher productive spinning machine driven by motor, control and facilitated manual. The machine will be appropriate for middle scale industry level operators.

1.3.2 Specific objectives

The **specific objectives** of the project are to:

- ✓ Study different ways and mechanisms and types of spinning machine
- ✓ Study the spinning and winding parameters like speed, spine length, fiber tension, yarn tension etc. on yarn quality,
- ✓ Select appropriate materials to the machine
- ✓ Apply the parameters to the design of the machine
- ✓ design a better spinning which is capable of spinning on a number of spools with low cost and simple in operation,
- ✓ Make the design ready to manufacture.

1.4 Scope of the study

The scope of this thesis work is to design an innovative motor driven cotton spinning machine for small and medium scale textile industries. This includes the power transmission, spinning system, sliver cotton drafting system and support structures.

1.5 Methodology

1.5.1 Subjects of the Study

The subjects of this project are cotton producers, micro and small scale and middle scale industry operators engaged in textile sectors.

1.5.2 Data Collection tools

The collection of data was taken via interview, questioners, observation of different textile industries in Ethiopia and performing experiments by working together with the respondents.

i. ***Questioners:*** to collect data with questioners a maximum of 15 questions and will be prepared and distribute for different micro and small scale and middle scale industry operators of textile sectors. Sufficient time will be given to the respondents based on the research time this helps them to think about the questions and give the right answer. These questions will be to get data about their personal institutional information and status, machine capacity of production, the materials of spinning, winding and accessories, machine cost, defects and problems of the machine and the likes. Open and closed questioners will be applied.

ii. ***Interviews:*** to collect data with interviews, not more than eight interview questions will be prepared for one person and around ten respondents will be asked. These interviews will help to know about their interest to change their working system and use improved technological machines, demand and capacity of production. Formal and informal interviews will be used.

iii. ***Observation:*** to collect data from the observing of textile industries, by preparing some criteria to be observed and measured while operating the machine like mechanisms of spinning and winding, length of fiber span, speed of the machine, quality of the fiber, sizes/ dimensions of the machine, and accessories of the machine.

iv. ***Performing experiments:*** performing experiments will help to know different parameters like the tensile strength and the appropriate speeds and tension of the yarn specially used by local wavers.

1.5.3 Data Treatment

After collecting all the necessary data based on the above methods, assessing and analyzing the data will be started with different methods in order to know what is the majority's problems and interest and give solutions from the side of engineering. So, the appropriate mechanisms selected. Then, the design work towards avoiding their problem and satisfying their interest will be done.

1.5.4 Designing of the Machine

The Engineering concepts and formulas will be applied to design the machine elements, to determine the strength, geometrical values and speeds. The design of the machine on the computer will be done using ***Auto CAD***.

CHAPTER TWO

LITERATURE REVIEW

The term ‘Textile' is a Latin word which comes from the word ‘texere' which means ‘to weave'. Textile originally referred to a woven fabric but latter on the term textile as well as the plural textiles refers to fibers, filaments and yarns.

Textile machineries refer to the various machineries used in different stages of manufacturing of textile products in textile industries. Textile machineries have a wide range of uses in various stages of production.

2.1 History of Textile Machinery

Textile Industry its evolution and progress forms an integral part of the history of textile machinery. Since the dawn of civilization, clothing was one of the man's primary needs. This led to the spinning of fiber into yarn and the cloth weaving which finally resulted in innovation of new technologies for textile industries. The first textile machinery used was the spinning wheel. It first developed in India and then in 14^{th} century it reached Europe[7].

Prior to the 17^{th} century, the manufacture of goods was performed on a limited scale by individual workers. This was usually on their own premises (such as weavers' cottages) – In the early 18th century, artisans were inventing ways to become more productive. Silk, Wool, Fustian, were being eclipsed by Cotton which was becoming the most important textile. This set the foundations for the changes. Historians agree that the Industrial Revolution was one of the most important events in history.

The industrial revolution changed the nature of work and society. Opinion varies as to the exact date, but it is estimated that the First Industrial Revolution took place between 1750 and 1850, and the second phase or Second Industrial Revolution between 1860 and 1900. The three key drivers in these changes were textile manufacturing, iron founding and steam power.

The textile industry has several uses for winding machines. The most common is thread winding, which may involve winding the thread onto a card, bobbin, or spool. Other materials that need a winding machine include ribbons, yarns, and cords. Sometimes companies combine the winding machine with another machine, such as a twister, to spool a product like rope.

2.1.1 Hand Spinning

Spinning is an ancient textile art in which plant, animal or synthetic fibers are twisted together to form yarn. For thousands of years, fiber was spun by hand using simple tools, the spindle and distaff. Only in the High Middle Ages did the spinning wheel increase the output of individual spinners, and mass-production only arose in the 18th century with the beginnings of the Industrial Revolution. Hand-spinning remains a popular handicraft[7].

In the most primitive type of spinning, tufts of animal hair or plant fiber are rolled down the thigh with the hand, and additional tufts are added as needed until the desired length of spun fiber is achieved. Later, the fiber is fastened to a stone which is twirled round until the yarn is sufficiently twisted, whereupon it is wound upon the stone and the process repeated over and over.

The next method of twisting yarn is with the spindle, a straight stick eight to twelve inches long on which the thread is wound after twisting. At first the stick had a cleft or split in the top in which the thread was fixed. Later, a hook of bone was added to the upper end. The bunch of wool or plant fibers is held in the left hand. With the right hand the fibers are drawn out several inches and the end fastened securely in the slit or hook on the top of the spindle. A whirling motion is given to the spindle on the thigh or any convenient part of the body. The spindle is then dropped, twisting the yarn, which is wound on to the upper part of the spindle. Another bunch of fibers is drawn out, the spindle is given another twirl, and the yarn is wound on the spindle, and so on.

Figure 2.1a. Woman spinning. Detail from an Ancient Greek Attic white-ground oinochoe, ca. 490 BC, from Locri, Italy. British Museum, London.

Figure 2.1b. *The Spinner* by William-Adolphe Bouguereau shows a woman hand-spinning using a drop spindle. Fibers to be spun are bound to a distaff held in her left hand.

A spindle containing a quantity of yarn rotates more easily, steadily, and continues longer than an empty one; hence, the next improvement was the addition of a weight called a spindle whorl at the bottom of the spindle. These whorls are discs of wood, stone, clay, or metal with a hole in the center for the spindle, which keep the spindle steady and promote its rotation. Spindle whorls appeared in the Neolithic era.

Figure 2.2 Modern top-whorl drop spindles

In medieval times, poor families had such a need for homespun yarn to make their own cloth and clothes that practically all girls and unmarried women would keep busy spinning, and spinster became synonymous with an unmarried woman. Subsequent improvements with spinning wheels and then mechanical methods made hand-spinning increasingly uneconomic, but as late as the twentieth century hand-spinning remained widespread in poor countries.

2.1.2 Spinning Wheel

A **spinning wheel** is a device for spinning thread or yarn from natural or synthetic fibers. Spinning wheels appeared in Asia, probably in the 11^{th} century, and very gradually replaced hand spinning with spindle and distaff.

The spinning wheel replaced the earlier method of hand spinning with a spindle. The first stage in mechanizing the process was mounting the spindle horizontally so it could be rotated by a cord encircling a large, hand-driven wheel. The great wheel is an example of this type, where the fiber is held in the left hand and the wheel slowly turned with the right. Holding the fiber at a slight angle to the spindle produced the necessary twist. The spun yarn was then wound onto the spindle by moving it so as to form a right angle with the spindle. This type of wheel, while known in Europe by the 14th century, was not in general use until later. It ultimately was used there to spin a variety of yarns until the beginning of the 19th century and the mechanization of spinning[7].

In general, the spinning technology was known for a long time before being adopted by the majority of people, thus making it hard to fix dates of the improvements. In 1533, a citizen of Brunswick is said to have added a treadle, by which the spinner could rotate her spindle with one foot and have both hands free to spin.

There are different types of hand-powered spinning wheels. Hand powered spinning wheels are powered by the spinner turning a crank for flywheel with their hand, as opposed to pressing pedals or using a mechanical engine.

I. Charkha

The charkha, a small, portable, hand-cranked wheel, is ideal for spinning cotton and other fine, short-staple fibers, though it can be used to spin other fibers as well

Figure 2.3 Mohandas Gandhi spinning yarn on a charkha.

II. Great Wheel

The great wheel was one of the earlier types of spinning wheel. The fiber is held in the left hand and the wheel slowly turned with the right. This wheel is thus good for using the long-draw spinning technique, which requires only one active hand most of the time, thus freeing a hand to turn the wheel. The great wheel is usually used to spin wool, and can only be used with fiber preparations that are suited to long-draw spinning[7].

Figure 2.4 Spinning wool on a great wheel at a demonstration in the Conner Prairie living history museum loom house

III. Treadle Wheel

This type of wheel is powered by the spinner's foot rather than their hand or a motor. The spinner sits and pumps a foot treadle that turns the drive wheel via a crankshaft and a connecting rod. This leaves both hands free for drafting the fibers, which is necessary in the short draw spinning technique, which is often used on this type of wheel. The old-fashioned pointed distaff spindle is not a common feature of the treadle wheel. Instead, most modern wheels employ a flyer-and-bobbin system which twists the yarn and winds it onto a spool simultaneously. These wheels can be single - or double-treadle; which is a matter of preference and does not affect the operation of the wheel.

IV. **Double Drive**

The double drive wheel is named after its drive band, which goes around the spinning wheel twice. The drive band turns the flyer, which is the horse-shoe shaped piece of wood surrounding the bobbin, as well as the bobbin. Thus both the flyer and bobbin rotate to twist and winds the yarn onto the bobbin [7].

Figure 2.5 A double drive wheel

V. **Single Drive**

A single drive wheel has one drive band, which goes around the fly-wheel and the bobbin or the flyer. Most of the drive bands for single drive wheels are made from synthetic cord, which is elastic and does not slip easily on the wheel.

While the spinner is making new yarn, the bobbin and the flyer turn in unison, but when the spinner wants to wind the yarn onto the bobbin, the bobbin or the flyer slows down and thus the yarn winds on. The one part slows down because of the brake band, which loops over that element. The tighter the brake band is, the more pull on the yarn, because the more friction the bobbin has to overcome in order to turn in sync with the flyer[7].

Figure 2.6 A single-drive wheel with the drive band around flyer and brake on the bobbin

VI. Spinning Jenny

The **spinning jenny** is a multi-spool spinning frame. It was invented in 1764 by James Hargreaves in Stanhill, Oswaldtwistle, and Lancashire in England. The device reduced the amount of work needed to produce yarn, with a worker able to work eight or more spools at once. This grew to 120 as technology advanced.

The spinning jenny succeeded because it held more than one ball of yarn, making more yarn in a shorter time and reducing the overall cost. The spinning jenny would not have been such a success if the flying shuttle had not been invented and installed in textile factories. Its success was limited in that it required the rovings to be prepared on a wheel, and this was limited by the need to card by hand[7].

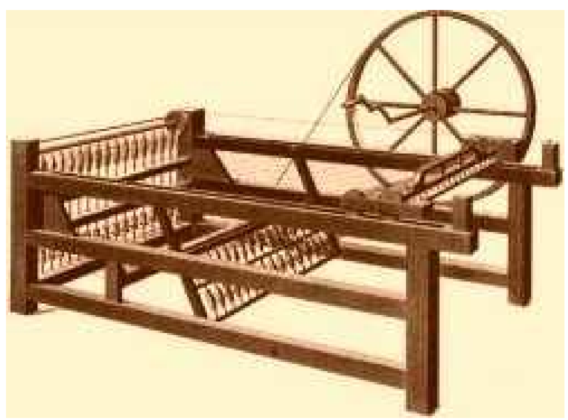


Figure 2.7 Spinning jenny

It continued in common use in the cotton and fustian industry until about 1810. The spinning jenny was superseded by the spinning mule. The jenny was adapted for the process of slubbing being the bases of the slubbing billy. The jenny was adapted for the process of slubbing being the bases of the slubbing billy.

VII. Vii Spinning Frame

The **spinning frame** is an Industrial Revolution invention for spinning thread or yarn from fibers such as wool or cotton in a mechanized way. It was developed in 18th century Britain by Richard Arkwright and John Kay.

In 1760 England, yarn production from wool and cotton was still a cottage industry in which fibers were carded and spun by hand using a spinning wheel. As the textile industry expanded its markets and adopted faster machines, yarn supplies became scarce especially due to innovations such as the doubling of the loom speed after the invention of the flying shuttle. High demand for yarn spurred invention of the spinning jenny in 1765, followed closely by the invention of the spinning frame, later developed into the water frame (patented in 1769). Mechanisms had increased production of yarn so dramatically that by 1830 the yarn cottage industry in England could no longer compete and all spinning was carried out in factories.

Richard Arkwright employed John Kay to produce a new spinning machine that Kay had worked on with (or possibly stolen from) another inventor called Thomas Highs. With the help of other local craftsmen the team produced the spinning frame, which produced a stronger thread than the spinning jenny produced by James Hargreaves. The frame employed the draw rollers invented by Lewis Paul to stretch, or attenuate, the yarn.

A thick 'string' of cotton roving was passed between three sets of rollers, each set rotating faster than the previous one. In this way it was reduced in thickness and increased in length before a strengthening twist was added by a bobbin-and-flyer mechanism.

Too large to be operated by hand, the spinning frame needed a new source of power. Arkwright at first experimented with horses, but decided to employ the power of the water wheel, which gave the invention the name 'water frame'.

For some time, the stronger yarn produced by the spinning frame was used in looms for the lengthwise "warp" threads that bound cloth together, while hand powered jennies provided the weaker yarn used for the horizontal filler "weft" threads. The Jennies required skill but was inexpensive and could be used in a home. The spinning frames required significant capital but required little skill.

2.1.3 Textile manufacture during the Industrial Revolution

Textiles – Cotton spinning using Richard Arkwright's water frame, James Hargreaves's Spinning Jenny, and Samuel Crompton's Spinning Mule (a combination of the Spinning Jenny and the Water Frame). This was patented in 1769 and so came out of patent in 1783. The end of the patent was rapidly followed by the erection of many cotton mills. Similar technology was subsequently applied to spinning worsted yarn for various textiles and flax for linen[7].

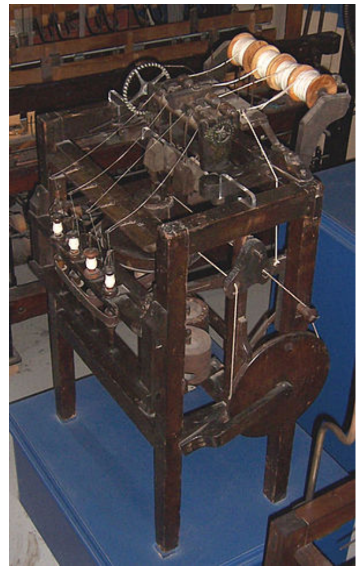


Figure 2.8 Model of spinning jenny in the Museum of Early Industrialisation, Wuppertal, Germany

Figure 2.9 The only surviving example of a spinning mule built by the inventor Samuel Crompton

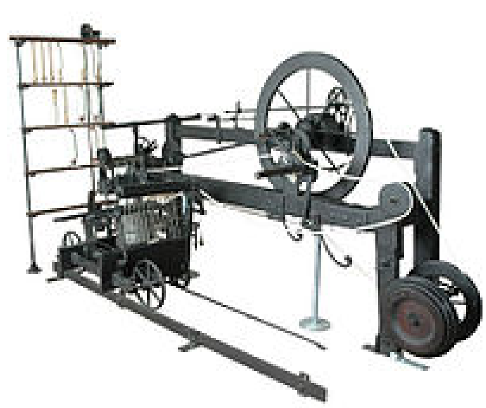


Figure 2.10 An Arkwright water frame that was made in 1775.

The textile industry grew out of the industrial revolution in the 18th Century as mass production of yarn and cloth became a mainstream industry.

In 1734 in Bury, Lancashire, John Kay invented the flying shuttle one of the first of a series of inventions associated with the cotton industry. The flying shuttle increased the width of cotton cloth and speed of production of a single weaver at a loom. Resistance by workers to the perceived threat to jobs delayed the widespread introduction of this technology, even though the higher rate of production generated an increased demand for spun cotton [7].

Figure 2.11 Shuttles

In 1761, the Duke of Bridgewater's canal connected Manchester to the coal fields of Worsley and in 1762, Matthew Boulton opened the Soho Foundry engineering works in Handsworth, Birmingham. His partnership with Scottish engineer James Wattresulted, in 1775, in the commercial production of the more efficient Watt steam engine which used a separate condensor.

In 1764, James Hargreaves is credited as inventor of the spinning jenny which multiplied the spun thread production capacity of a single worker — initially eightfold and subsequently much further. Others credit the original invention to Thomas Highs. Industrial unrest and a failure to patent the invention until 1770 forced Hargreaves from Blackburn, but his lack of protection of the idea allowed the concept to be exploited by others. As a result, there were over 20,000 Spinning Jennies in use by the time of his death. Again in 1764, Thorp Mill, the first water-powered cotton mill in the world was constructed at Royton, Lancashire, England. It was used for carding cotton. With the spinning and weaving process now mechanized, cotton mills cropped up all over the North West of England.

2.1.4 Nineteenth Century Developments

With the Cartwright Loom, the Spinning Mule and the Boulton & Watt steam engine, the pieces were in place to build a mechanized textile industry. From this point there were no new inventions, but a continuous improvement in technology as the mill-owner strove to reduce cost and improve quality. Developments in the transport infrastructure; that is the canals and after 1831 the railways facilitated the import of raw materials and export of finished cloth.

Firstly, the use of water power to drive mills was supplemented by steam driven water pumps, and then superseded completely by the steam engines. For example Samuel Greg joined his uncle's firm of textile merchants, and, on taking over the company in 1782, he sought out a site to establish a mill. Quarry Bank Mill was built on the River Bollin at Styal in Cheshire. It was initially powered by a water wheel, but installed steam engines in 1810. Quarry Bank Mill in Cheshire still exists as a well preserved museum, having been in use from its construction in 1784 until 1959. It also illustrates how the mill owners exploited child labor, taking orphans from nearby Manchester to work the cotton. It shows that these children were housed, clothed, fed and provided with some education. In 1830, the average power of a mill engine was 48 hp, but Quarry Bank mill installed a new 100 hp water wheel. William Fairbairn addressed the problem of line-shafting and was responsible for improving the efficiency of the mill. In 1815 he replaced the wooden turning shafts that drove the machines at 50rpm, to wrought iron shafting working at 250 rpm, these were a third of the weight of the previous ones and absorbed less power.

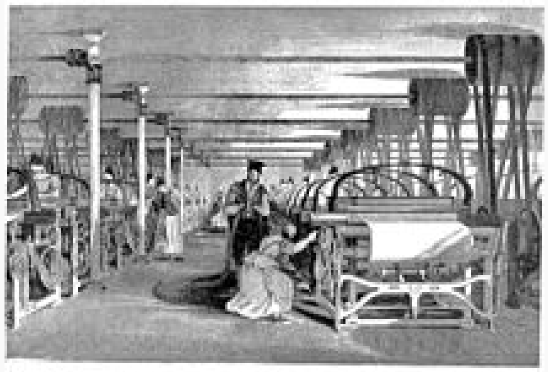


Figure 2.12 A Roberts's loom in a weaving shed in 1835. Note the wrought iron shafting, fixed to the cast iron columns

Secondly, in 1830, using a 1822 patent, Richard Roberts manufactured the first loom with a cast iron frame, the Roberts Loom. In 1842 James Bullough and William Kenworthy, made the Lancashire Loom . It is a semi automatic power loom. Although it is self-acting, it has to be stopped to recharge empty shuttles. It was the mainstay of the Lancashire cotton industry for a century, when the [Originally, power looms were shuttle-operated but in the early part of the 20th century the faster and more efficient shuttle less loom came into use. Today, advances in technology have produced a variety of looms designed to maximize production for specific types of material. The most common of these are air-jet looms and water-jet looms. Industrial looms can weave at speeds of six rows per second and faster[7].

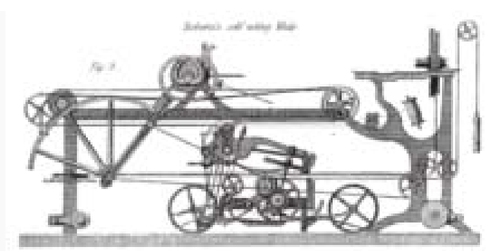


Figure 2.13 Roberts self acting mule with quadrant gearing

Thirdly, also in 1830, Richard Roberts patented the first self-acting mule. Staly bridge mule spinners strike was in 1824, this stimulated research into the problem of applying power to the winding stroke of the mule. The draw while spinning had been assisted by power, but the push of the wind had been done manually by the spinner; the mule could be operated by semiskilled labor. Before 1830, the spinner would operate a partially-powered mule with a maximum of 400 spindles after; self-acting mules with up to 1300 spindles could be built.

The industrial revolution changed the nature of work and society. The three key drivers in these changes were textile manufacturing, iron founding and steam power. Textile production in England peaked in 1926, and as mills were decommissioned, many of the scrapped mules and looms were bought up and reinstated in India. The demographic change made by the Great European War, had made the labor-intensive industry un-profitable in England, but in India and later China it was an aid to development [7].

2.2 Ethiopia and Spinning

We grew up watching members of our family and villagers spinning cotton and winding yarn on spindle with an “INZERT” made from wood with their hand .The traditional wooden hand drop spindle used here in Ethiopia for number of centuries to spin cotton. Cotton culture runs deep here in Ethiopia, one of the last authentically organic environments where cotton is grown, and the ART of hand spinning of cotton in this manner dates back millennia here and our artisans are among the finest[4].

Traditional clothes in Ethiopia are exotic and made with culture-based cloth that represents our nation and Ethiopian's sense of pride and dignity.

Our cloth came from the old ancient culture of Ethiopia. Ethiopian traditional cloth is made of cotton that is woven together in long strips and then sewn together to make cloth. It takes about two to three weeks to make enough cloth for a dress.

Most people in Ethiopia wear the traditional cloth called "yahager lebse." On some cloth shiny threads are used to decorate it and make it more elegant. On the bottom of the skirt there can be a lot of patterns.

The traditional clothes are different for men and women. The men wear pants and a shirt all the way to the knee with a well-designed sweater and a piece of cloth on top. The color of the collar is white. Women wear dresses with a piece of cloth on top. It is culled "netela." For most of the women, the cloth is white but has other colors on the bottom, which gives it a unique look. The women also wear necklaces and also bracelets on our arms and feet. The bracelets are made from silver and gold[4].

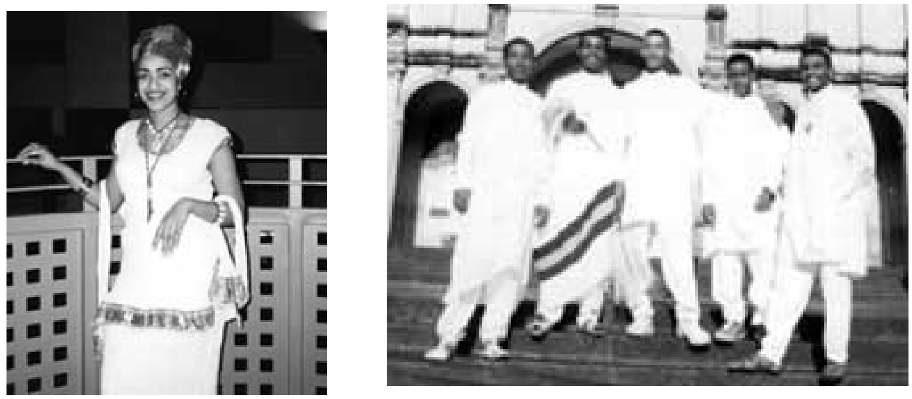


Figure 2.14 Ethiopian traditional clothing

In the countryside, traditional clothes are worn every day but not in the cities and towns. In the cities, many older people wear the traditional clothes in a daily basis. But youngsters wear western clothes like Americans most of the time. But on special occasions, like holiday time for example, we wear the traditional clothes. We normally wear them for New Years, Christmas, and weddings. Even in the United States Ethiopians wear out traditional clothes for Ethiopian holidays[4].

We are proud to wear our traditional clothes because they represent our beautiful country of Ethiopia.

2.2.1 Indigenized knowledge in weaving

Weaving is different from other crafts in that its origins in Ethiopia are much more recent and probably do not go back even one millennium. Cotton was cultivated and cloth produced in Meroe in Sudan in ancient time and cloth was imported in to Ethiopia as early as the first century A.D. (Simoons 1960, 186). The evidence for the Aksumite civilization producing woven cloth is inconclusive and relies on the fact that loom weights were excavated and an allusion made to Aksumites wearing white kilts or loin cloths (Munro-Hay 1991, 195). Certain species of cotton seem to be indigenous, and the introduction of cotton cultivation and weaving by Arabs probably took place in Northern Ethiopia around the 12th century AD (Gerves 1988, 219). Weaving in Northern Ethiopia, according to observers from the Portuguese travelers onwards, was often carried out by Muslims and Falashas (quoted in Pankhurst 1961, 284; 286). In the south, weaving tradition probably did not spread to Southern Ethiopia till several centuries later, although it existed prior to the late 19th century conquest (Amborn 1990, 158-9; 180-2)[10].

Although they were not as strictly segregated as smiths, tanners and potters, weavers were looked down upon in Northern Ethiopia, and the occupation was associated with Muslims and Falashas (Simoons 1961, 187; Pankhurst 1990, 60; 224). In southern Ethiopia weavers are not generally considered a separate group and are not despised. Farmers in many areas can become weavers without opprobrium. However, in some of the ancient kingdoms such as Kafa, they did form separate groups working for the elite. In urban centres weavers who are full time craftsmen are despised. Weavers from Gamo and in particular the Dorze have dominated this occupational niche.

The spread of wearing cotton in Northern Ethiopia may have been gradual (Simoons 1991, 186). In the early sixteenth century Duarte Borbosa suggested that a law permitted only certain families and ranks to wear cloth, and Manual de Almeida in the early 17th century noted that cloth was generally less common among women than men, and poor women wore tanned ox-skins (quoted in Simoons 1960, 186).

The basic pit loom consists of four upright posts connected by two horizontal poles; two harnesses made from wood with a long rope made from the treadles of the loom, in front of which is the reed, which rests inside the wooden frame of the beater. The reed is composed of vertical bamboo pieces with a space between each and holds up to 600 threads. At the front of the loom is a breast beam around which the finished cloth is wound. These days the weft thread is wound on a bobbin using a winder, and is placed in the shuttle (Zelinsky-Cartledge and Cartledge 1999, 246-249; see also Pankhurst 1968, 259; 1990, 225-6).

In terms of products in the past in the south shorts used to be made in Kafa and Konso but these have long disappeared. Trousers were replaced more rapidly than other items, and *shemma shawls* have been the most lasting items. Shawls known *asfot'a* entirely made from coloured thread, most commonly using two colours resulting in a chequered pattern, have become increasingly popular. These have been made by weavers in some parts of the south only in the past twenty years and are preferred on the grounds of being stronger, more colourful and requiring less washing (Zelinsky-Cartledge and Cartledge 1997, 252).

Weavers nowadays produce a range of artefacts, from thick blankets, *gabi* and *bulluko,* to thin shawls, *net'ela ,* and dresses, *qemis.* Shawls and dresses have coloured *t'ilet* border, which traditionally had a single colour made using natural dyes. The colour of the border and the way the shawl was worn was in some cases an indication of status (Messing 1960). Particularly in urban areas, the borders of shawls and dresses have intricate geometrical designs often using several colours, and sometimes silver or golden thread[10].

The decline in weaving resulted from competition from cheaper imports in parts of the country along trade routes already in the 1880s. However, the demand for cloth increased *in* the 20th century as woven products gradually substituted hide clothing, throughout most orthe south, Moreover, the imports of thread in the early part of the century actually encouraged local production (Pankhurst 1964, 225). However, just as this process was gaining ground, imported textiles and sewing machines began to take over in more accessible areas. By the early 70s, Lange (1982, 263) noted that: 'The few weavers who have survived the impact of tailors and sewing machines are found in the remoter regions of the Kafa highlands'. During the past two decades, locally produced factory blankets and textiles have also threatened weaving and in the

90s bulk second-hand clothes, called *salvaj,* have become extremely cheap in comparison with even local factory-produced cloth sewn by tailors.

The basic loom has remained unchanged for more than a century. However, the use of factory yarn not just for the warp but also for the weft has been increasing. Likewise, the trend of introducing a greater variety of coloured threads for the borders has been increasing. In addition to producing items such *as fat'a* entirely from factory-produced thread, weavers especially in towns such as Shashemene have also recently improved their techniques so that the border designs on *net 'ela* shawls are visible on both sides and the patterns have become more intricate, elaborate and wide.

Despite competition from imports and local factory produce, woven cloth is unlikely to disappear, even though its use for blanket is becoming more common than for clothing. Gender and generation are important factors, in that the elderly and women are more attached to locally woven clothes. Cheaper factory produced blankets are also replacing the famous thick *bulluko* woven blankets and the less thick *gabi*[10].

There are also cultural reasons why local waving is likely to survive. Throughout Ethiopia at the end of the 20th century *netala* shawls are still worn by women for social occasions, notably for funerals, where the custom *ofmadegdeg,* reversing the border and wearing it at the top as a sign of mourning still retains a strong symbolic value. In some towns one can also notice a resurgence of Ethiopian men wearing 'national dress' with a woven shawl during public holidays as a sign of cultural pride. The designs of the borders on cloths have also been elaborated. In addition to geometric designs, the borders represent objects From the natural world such as plants, stars, flowers and palm trees; from the animal world such as fishes, ducks, and lions; objects from daily and religious life such as mesob eating baskets, locks and crosses. Symbols of modernity such as the television, traffic lights, airlines, buses and roads have also been added to the repertoire. There has also been a fashion of making the borders increasingly wide, with status increasing with width and cost to the extent that dresses consisting mainly or even entirely of the border have been produced. This is a case of the influence of fashion and competition for ostentatious displays of wealth. However, in general, apart from some conservative elders, men have almost ceased wearing traditional woven clothing except for special occasions, and younger women seldom wear dresses made from locally woven materials, although they may retain a *net 'ela* shawl especially for funerals[10].

2.3 YARN CHARACTERISTIC

Yarn occupies the intermediate position in the production of fabric from raw material. Yarn results are very essential, both for estimating the quality of raw material and for controlling the quality of fabric produced. The important characteristics of yarn are[3]:

• Yarn Count

• Yarn Twist

• Yarn Strength & Elongation

• Yarn Evenness

• Yarn Hairiness etc.

2.3.1 Yarn Count

The fineness of the yarn is usually expressed in terms of its linear density or count. There are a number of systems and units for expressing yarn fineness. But they are classified as DIRECT SYSTEM, INDIRECT SYSTEM.

For the determination of the count of yarn, it is necessary to determine the weight of a known length of the yarn. For taking out known lengths of yarns, a wrap-reel is used. The length of yarn reeled off depends upon the count system used. One of the most important requirements for a spinner is to maintain the average count and count variation within control[3].

2.3.2 Yarn Count Variation

The term count variation is generally used to express variation in the weight of a lea (a unit of length of thread or yarn) and this is expressed as C.V.%. The number of samples and the length being considered for count checking affects this. While assessing count variation, it is very important to test adequate number of leas. After reeling the appropriate length of yarn, the yarn is conditioned in the standard atmosphere for testing before it's weight is determined[3].

2.3.3 Yarn Twist

Twist is defined as the spiral disposition of the components of yarn, which is generally expressed as the number of turns per unit length of yarn, e.g. turns per inch, turns per meter, etc. With increase in twist, the yarn strength increases first, reach a maximum and then decreases. Direction of twist is expressed as "S"-Twist or "Z"-Twist. Direction depends upon the direction of rotation of the twisting element. Twist take up is defined as, "The decrease in length of yarn on twisting, expressed as a percentage of the length of yarn before twisting[3].

Twist Standards

Cotton combed knitting T.M. = 3.4 to 3.6

Cotton combed weaving T.M. = 3.7 to 3.8

Cotton carded knitting T.M. = 3.8 to 4.0

Cotton carded weaving T.M. = 3.9 to 4.2

2.3.4 Yarn Strength & Elongation

Breaking strength, elongation, elastic modulus, resistance abrasion etc are some important factors, which will represent the performance of the yarn during actual use or winding and weaving and further processing.

Strength testing is broadly classified into two methods.

1. Single End Strength Testing
2. Lea Strength

1. Single End Strength Testing

During routine testing, both the breaking load and extension of yarn at break are usually recorded for assessing the yarn quality. Most of the instruments record the load-elongation diagram also[3].

Various parameters such as initial elastic modulus, the yield point, the tenacity or elongation at any stress or strain, breaking load, breaking extension etc can be obtained from the load-extension diagram.

Two types of strengths can be determined for a yarn

1. Tensile strength -load is applied gradually
2. Ballistic strength - applying load under rapid impact conditions

2. Skein strength or lea strength

The skein breaking strength was the most widely used measure of yarn quality in the cotton textile industry. The measurement of yarn quality by this method has certain drawbacks.

Firstly, in most of the subsequent processing, such as winding, warping or weaving, yarn is used as single stranding not in the form of a skein except occasionally when sizing, bleaching, mercerizing or dyeing treatments are carried out on hanks.

Secondly, in the method used for testing skein strength, the rupture of a single strand at a weak place affects the result for the whole skein. Further, this method of test does not give an indication of the extensibility and elastic properties of a yarn, the characters which play and important role during the weaving operations.

However, since a large size sample is used in a skein test as against that in a single strand test, the sampling error is less. The skein used for strength test can be used for determination of the linear density of the yarn as well[3].

After finding out skein strength, broken skeins are also weighed to determine the linear density. The most common skein used is the lea and the results of lea strength tests are expressed as C.S.P., which is the product of the linear density (count) of the yarn in the English system (Ne) and the lea breaking strength expressed in lbs. In view of the fact that C.S.P. is much less dependent on yarn count than on strength, especially when count differences are small, C.S.P. is the most widely used measure of yarn quality.

2.3.5 Yarn Evenness

Non-uniformity in variety of properties exists in yarns. There can be variation twist, bulk, strength, elongation, fineness etc. Yarn evenness deals with the variation in yarn fineness. This is the property, commonly measured, as the variation in mass per unit length along the yarn, is a basic and important one, since it can influence so many other properties of the yarn and of fabric made from it. Such variations are inevitable, because they arise from the fundamental nature of textile fibers and from their resulting arrangement. Accordingly, there are limits to the achievable yarn evenness[3].

1. Unevenness / Irregularity

The mass per unit length variation due to variation in fiber assembly is generally known as "IRREGULARITY" or "UNEVENNESS". It is true that the diagram can represent a true reflection of the mass or weight per unit length variation in a fiber assembly. For a complete analysis of the quality, however, the diagram alone is not enough. It is also necessary to have a numerical value that represents the mass variation. The mathematical statistics offer two methods

1. The irregularity U%: It is the percentage mass deviation of unit length of material and is caused by uneven fiber distribution along the length of the strand.

2. The coefficient of variation C.V.%

1. Imperfections

Yarns spun from staple fibres contain "IMPERFECTIONS". They are also referred to as frequently occurring yarn faults. They can be subdivided into three groups

1. Thin places

2. Thick places

3. Neps

The reasons for these different types of faults are due to raw material or improper preparation process. A reliable analysis of these imperfections will provide some reference to the quality of the raw material used[3].

2.3.6 Yarn Hairiness

Hairiness is a measure of the amount of fibres protruding from the structure of the yarn. In general, yarn spun with cotton show high level of hairiness due to the following reasons[3].

I. High short fiber content in mixing.
II. Low uniformity ratio.
III. High spindle speeds.

2.4 Spinning System

There is an extensive range of different spinning systems, not all of which are in wide commercial use; many are still experimental or, having reached the commercial stage, have been withdrawn from the market. A classification of the better known spinning systems is given Table 3.1, in which the various techniques are grouped according to five basic methods. We will consider the fundamental principles of ring spinning systems as follows[11].

TABLE 2.1 Classification of Spinning System

Spinning methods	Common feature	Technique	Type of twisting action during spinning	Type of yarn structure produced for fiber consolidation	Trade names
Ring spinning	Ring and traveler	Single strand twisting	Real	Twisted: S or Z	Various
		Double-strand ply twisting	Real	Twisted: S or Z	Sirospun/Duospun
OE spinning	Break in the fiber mass flow to the twist insertion zone	Rotor spinning	Real	Twisted: Z + wrapped	Various
		Friction spinning	Real	Twisted: Z + wrapped	Dref II
Self-twist spinning	Alternative S and Z folding twist	False twisting of two fibrous strands positioned to self-ply	False	S and Z twisted	Repco
Wrap spinning	Wrap of fibrous core by either (a) filament yarn	Alternating S and Z twist plus filament wrapping	False	S and Z + filament wrapped	Selfil
	(b) staple fibers	Hollow spindle wrapping	False	Wrap	Parafil
		Air-jet fasciated wrapping	False	Wrapped + twisted	(Dref III, MJS, Plyfil)
Twistless	Coherence of the yarn constituents achieved by adhesive bonding or felting	Water-based adhesive	False	Bonded	Twilo
		Resin-based	False	Bonded	Bobtex
		Liquid felting	Zero	Felted	Periloc

The conventional ring spinning technique is currently the most widely used, accounting for an estimated 90% of the world market for spinning machines. The remaining systems in Table 3.1 are often referred to as *unconventional spinning processes* and, of these; rotor spinning has the largest market share.

Important aspects of any spinning system are the fiber types that can be spun, the count range, the economics of the process, and — very importantly — the suitability of the resulting yarn structure to a wide range of end uses. Except for the twistless-felting technique, all of the systems listed in Table 3.1 will spin man-made fibers, but because of processing difficulties and/or economic factors, the commercial spinning of 100% cotton yarns is mainly performed on ring and rotor spinning. With regard to process economics, the number of stages required to prepare the raw material for spinning, the production speed, the package size, and the degree of automation are key factors in determining the cost per kilogram of yarn, i.e., the unit cost [11].

Figures 2.15 and 2.16 shows that, although ring spinning has the widest spinnable count range, it has comparatively a very low production speed and therefore, even with automation, does not always offer the best process economics. The key to its dominance of world markets is the suitability of the ring-spun yarn structure and properties to a wide range of fabric end uses.

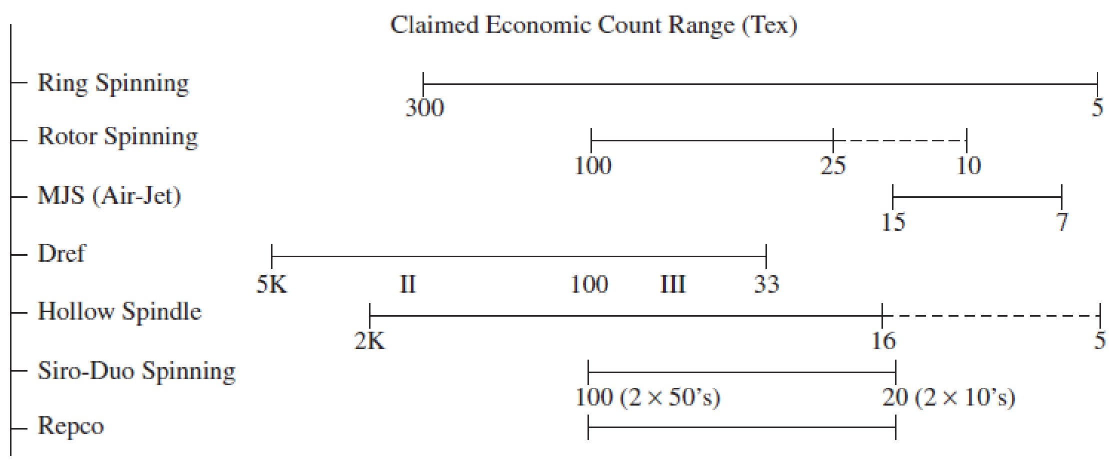


Figure 2.15 Economic count range of spinning systems

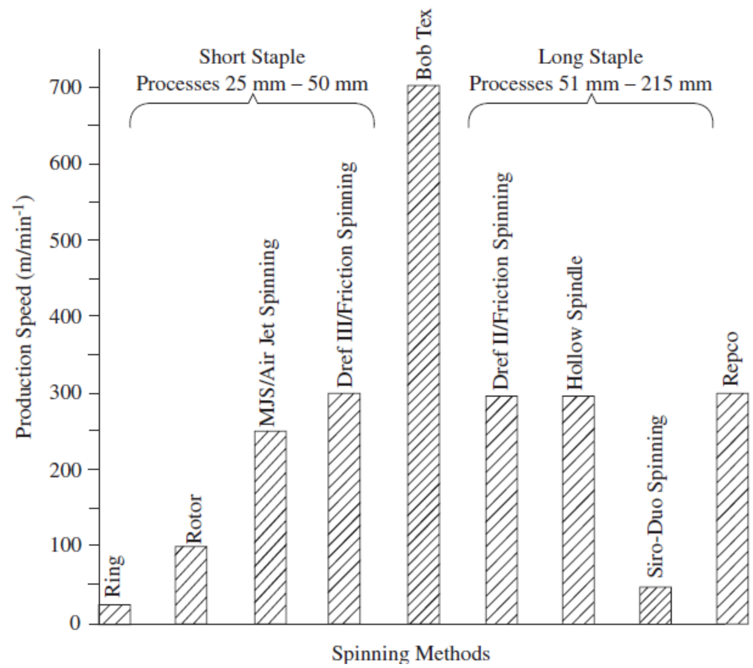


Figure 2.16 Production speeds of spinning systems.

Before explaining the operating principles of the listed spinning systems, it is useful to consider the technological equations applicable to all of them. All spinning systems have the three basic actions shown below for producing staple yarns[11]:

Basic Actions in Spinning Yarns

Attenuation of the feed material to the required count → Insertion of twist into the attenuated fiber mass to bind the fibers together → Winding of the spun yarn onto a bobbin to produce a suitable package

To spin a yarn from a given fiber type, certain specifications are required, such as the yarn count and, in particular, the level of twist. *The concept of twist factor was also explained*. These parameters are key variables in the technological equations that give us the production rate of any spinning system.

With respect to the yarn count, the required level of attenuation or total draft, D_T, of the system should allow for twist contraction. To do so in practice, a sample of yarn is spun to the required twist level, the resulting increase in count is determined, and the total draft is readjusted to give the specified count. Similar to the drafting considerations, the total draft is calculated as the ratio of the count of the feed material to the spinning machine and the count of the yarn. This value is then used to set the relative speeds of the drafting components of the machine [11].

$$D_T = \frac{Sliver\ tex}{Yarn\ tex} = \frac{Delivery\ roller\ surface\ speed\ (V_d)}{Feed\ roller\ surface\ speed\ (V_f)}$$

If N_I = the rotation speed of the twisting device used in spinning the yarn, then,

TF = the twist factor,

C_Y = the yarn count,

t = the level of twist, and N_I have the relation

$$TF = tC_y^{1/2} \quad \text{.......... 2.1}$$

$$t = \frac{N_I}{V_d} \quad \text{.......... 2.2}$$

Assuming that a machine has N_M number of spinning positions, commonly referred to as the number of spindles, and an operating efficiency of ε%, then the production per spindle, P_S, in kg/h^{-1} is

$$P_s = \frac{V_d C_Y 60}{10^6} \quad \text{.......... 2.3}$$

and the production per machine, P_M (again, in kg/h^{-1}) is

$$P_M = \frac{V_d C_Y 60 N_M \varepsilon}{10^8}$$

Substituting for V_d (Equations 2.1 and 2.2),

$$P_M = \frac{N_I C_Y^{3/2} 60 N_M \varepsilon}{TF\ 10^8} \quad \text{.......... 2.4}$$

The above equations are applicable to any spinning system. However, with some systems, the rotational speed of the yarn cannot be readily determined. It then may be estimated from twist (or some similar parameter, e.g., twist angle) and delivery speed measurements using Equation 2.2.

Out of all spinning system we will discuss only ring spinning system which is more appropriate system to combine the technology with the small scale spinning machines[11].

2.4.1 Ring and Traveler Spinning Systems

Definition: The ring and traveler spinning method is a process that utilizes roller drafting for fiber mass attenuation and the motion of a guide, called a *traveler,* freely circulating around a ring to insert twist and simultaneously wind the formed yarn onto a bobbin.

The ring and traveler combination is effectively a twisting and winding mechanism.

2.4.1.1 Conventional Ring Spinning

Figure 3.3 illustrates a typical arrangement of the ring spinning system. The drafting system is a 3-over-3 apron-drafting unit. The fibrous material to be spun is fed to the drafting system, usually in the form of a roving. Similar to the roving frame, the back zone draft is small, on the order of 1.25, and the front zone draft is much higher, around 30 to 40. The aprons are used to control fibers as they pass through the front zone to the nip of the front rollers. It is nevertheless important to note here that apron drafting systems are suitable for use only where the fiber length distribution of the material to be processed is not wide (i.e., not a significant amount of very short and very long fibers). When the standard distribution is higher, the material is more commonly drafted with a false-twister, which essentially replaces the drafting apron as depicted in Figure 3.4. This is typical of the ring spinning system for producing woolen yarns in which the slubbings from the woolen card are fed through the false-twister to the front rollers of the drafting system[11].

As Figure 2.17 shows, a yarn guide, called a *lappet,* is positioned below the front pair of drafting rollers. The ring, with the spindle located at its center, is situated below the lappet. Importantly, the lappet, the ring, and the spindle are coaxial. The traveler resembles a C-shaped metal clip, which is clipped onto the ring. A tubular-shaped bobbin is made to sheath the spindle so as to rotate with the spindle. The ring rail is geared to move up and down the length of the spindle; its purpose is to position the ring so that the yarn is wound onto the bobbin in successive layers, thereby building a full package, which is fractionally smaller in diameter than the ring. The yarn path is therefore from the nip of the front rollers of the drafting system, through the eye of the lappet and the loop of the traveler, and onto the bobbin [11].

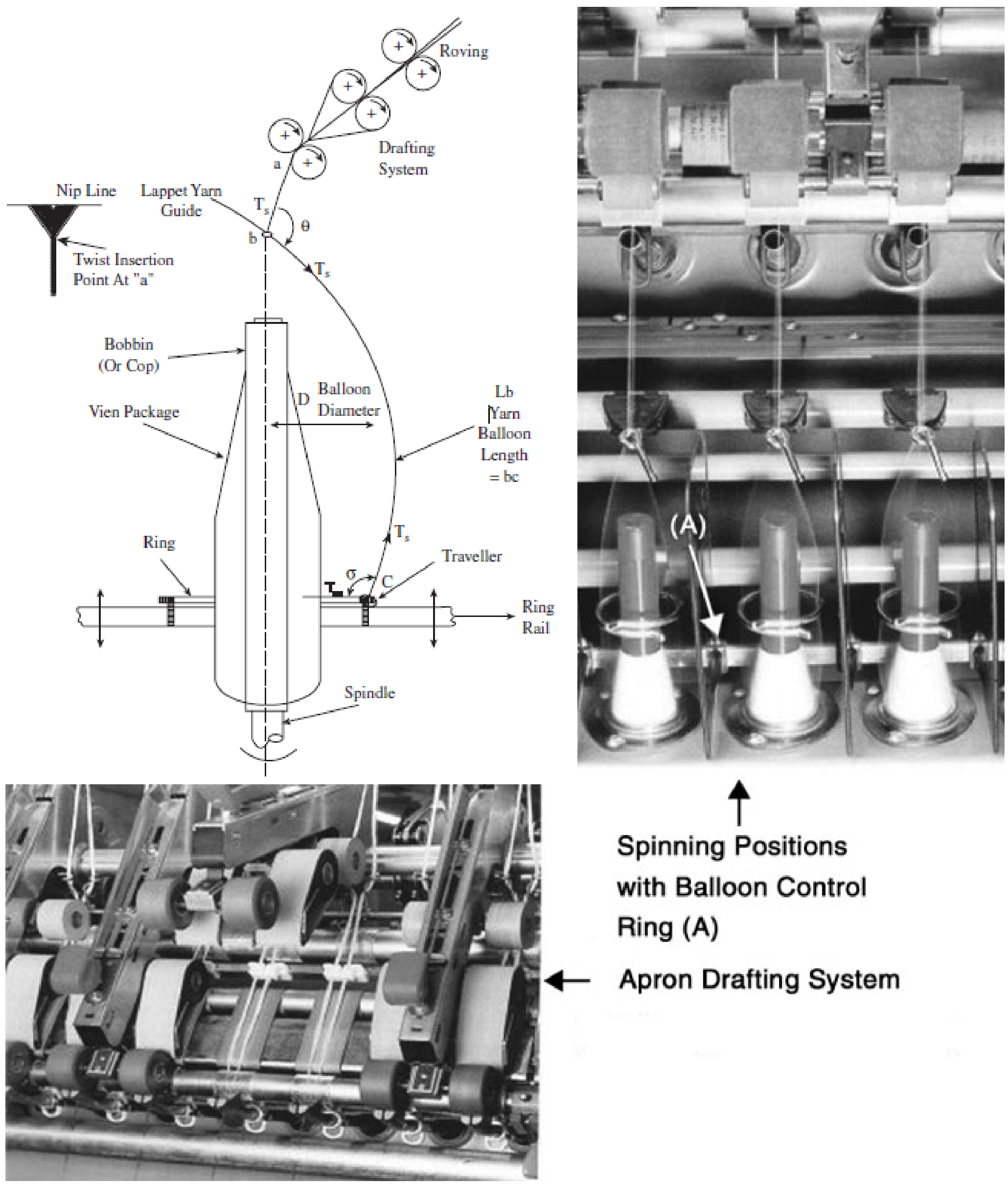


Figure 2.17 Example of ring spinning system. (Courtesy of Spindelfabrik Suessen Ltd.)

Essentially, the drafting system reduces the roving or slubbing count to an appropriate value so that, on twisting, the drafted mass of the required yarn count is obtained. As the front rollers push the drafted material forward, twist torque propagates up the yarn length (i.e., from *c* to *a*) and twists the fibers together to form a new length of yarn. The tensions and twist torque cause the fibers to come together to form a triangular shape between the nip line of the front drafting rollers and the twist insertion point at *a*. This shape is called the *spinning triangle.* The differing tensions between the fibers in the spinning triangle are considered to be responsible for an intertwining of the fibers during twisting, termed migration. The degree of migration strongly influences the properties of the spun yarn, and this feature of the yarn will be discussed in the later section [11].

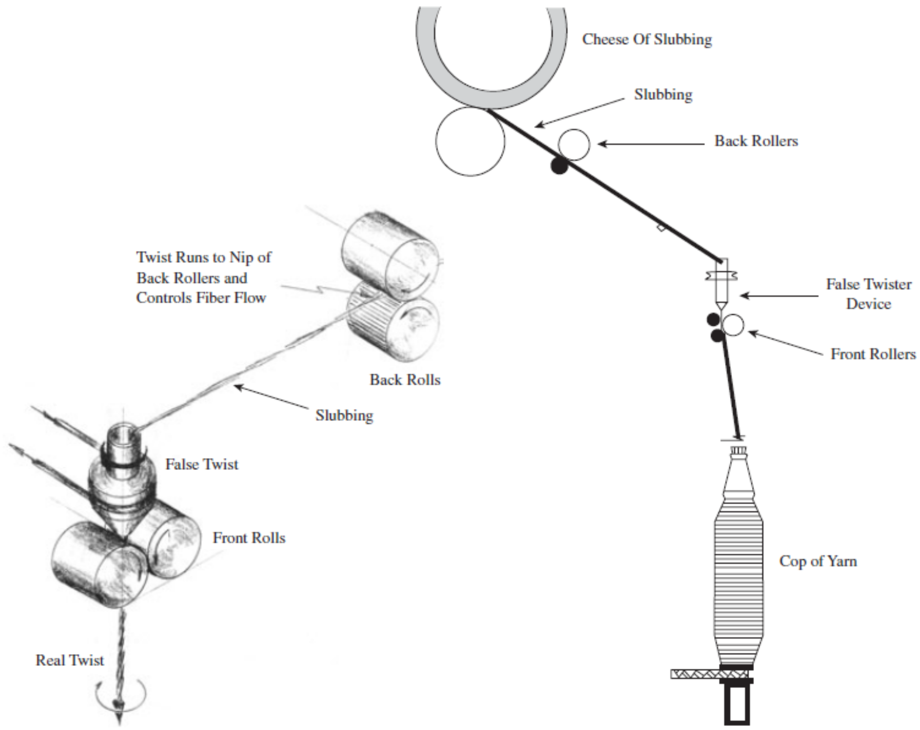


Figure 2.18 False-twist d rafting of woolen slubbing. (Courtesy of Lord, P. R., *Economics, Science & Technology of Yarn Production,* North Carolina State University, 1981.)

2.4.2 Spinning Tensions

The bobbin rotates with the spindle and, because the yarn passes through the traveler and onto the bobbin, the traveler will be pulled around the ring and the yarn pulled through the traveler and wound onto the bobbin. As the traveler circulates the ring, it carries with it the yarn length, L_b (= *bc*), extending from the lappet to the traveler. While L_b circulates the ring, the circular motion causes it to arc outward away from the bobbin. Air drag and the inertia of *Lb* result in the arc length having a slight spiral as it circulates with the traveler. The rotational speed of the spindle can be up to 25,000 rpm. The three-dimensional visual impression given by the circular motion of *Lb* is of an inflated balloon, termed the *spinning balloon* or *yarn balloon.* Hence, *Lb* is called the *balloon length, H* is the balloon height (the vertical distance from the plane of the ring to the plane of the lappet), and *D* is the balloon diameter. The forces generated by the motion of the traveler and the pulling of the yarn through the traveler result in yarn tensions that govern the actual shape of the spinning balloon[11].

The tensions generated in the yarn are indicated in Figure 6.3 and are related according to the following equations:

$$T_o = T_s\, e^{k\theta} \quad \text{......2.5}$$

$$T_w = T_R\, e^{P\alpha} \quad \text{......2.6}$$

where T_S = the spinning tension

T_O, T_R = the tensions in the balloon length at the lappet guide and at the ring and traveler, respectively

T_W = the winding tension

K = the yarn-lappet coefficient of friction

θ and α= the angles shown in the figure

P = yarn-traveler coefficient of friction

T_O and T_R are related by

$$T_O = T_R + mR^2\omega^2 \quad \text{......2.7}$$

where m = mass per unit length

These tensions are important to twist insertion and the winding of the yarn onto the bobbin, and also to end breaks during spinning.

Consider first the winding action. As the traveler is pulled around the ring, the centrifugal force, C, on the traveler will lead to a friction drag, F, where

$$F = \mu C \quad \text{......2.8}$$

$$C = MR_R\omega^2 \quad \text{......2.9}$$

where M = traveler mass

R_R = ring radius

ω = angular velocity of the traveler (= $2\pi N_t$)

The yarn must be wound onto the bobbin at the same linear speed, V_F, as the front drafting rollers are delivering fibers to be twisted. This means that F must be sufficient to make the traveler's rotational speed lag that of the spindle. Hence, if D_B is the bobbin diameter, then

$$N_s - N_t = \frac{V_F}{\pi D_B} \quad \text{......2.10}$$

Where N_s = spindle speed (rpm)

N_t = traveler speed (rpm)

The wind-up speed is therefore the difference between the spindle and traveler speed.

It is evident that, as the bobbin diameter increases with the buildup of the yarn, the traveler speed increases. The traveler speed will also change with the movement of the ring rail to form successive yarn layers on the bobbin. The common way of layering the yarn on the bobbin is known as a *cop build* in which each layer is wound in a conical form onto the package. The top of the cone is called the *nose* and the bottom the *shoulder*. In practice, it is found that the conical shape gives easy unwinding of the yarn without interference between layers, as the yarn length is pulled from the nose over the end of the bobbin. To make a cop build, the ring rail cycles up and down over a short length of the bobbin, with a slow upward and a fast downward motion. This increases the size of the shoulder more quickly than the nose. This cycling action of the ring rail progresses up the bobbin length in steps, each step taken when the shoulder size reaches almost the ring diameter [11].

2.4.3 Twist Insertion and Bobbin Winding

Let us consider now the action of twist insertion. From the definition, it is clear that one revolution of the traveler around the ring inserts one turn of twist into the forming yarn. However, for a fuller understanding of the twist insertion, we need to consider where the twist originates, the twist propagation, and twist variation caused by the cop build action.

Imagine two yarns of contrasting colors passed through the nip of the front drafting rollers and threaded along the yarn path to the bobbin. With the front drafting rollers and the ring rail stationary, and only the spindle driven, using high-speed photography, we would see that, within the first few rotations of the traveler, the twisting of the two yarns together originates in the balloon length between the lappet guide and the traveler. The action of twisting the two yarns together is called *plying* or *doubling*, so no ply twist would be seen in the length between the traveler and the spindle or between the lappet guide and the front drafting rollers. It should be clear from Equation 6.10 that no yarn would be wound onto the bobbin and that the rotational speed of the traveler would be equal to the spindle speed.

If the above experiment is repeated, but this time with the front drafting rollers and the ring rail operating, then the following would be observed. The initial length wound onto the bobbin will be of the two yarns in parallel and not twisted together. As above, the ply twist originates in the balloon length and, as it builds up in the balloon length, it propagates toward the delivery rollers. The frictional resistance at the lappet opposes the twist torque propagation, reducing the amount of twist passing the guide. The forces acting at the point of contact of the yarn and traveler prevent the twist torque propagating past the traveler toward the bobbin. However, as sections of the yarn leave the region of the balloon length and are pulled through the traveler and wound onto the bobbin, they retain the nominal twist given by Equation 6.2. Hence, under steady running conditions, the twist level in the balloon length will be greater than in the length above the lappet and slightly larger than in the length wound onto the bobbin.

The up-and-down movement of the ring rail gives a cyclic change in the balloon length during spinning. The length is shortest when the ring rail forms the nose of the cop build and longest at the shoulder. As the ring rail moves from the shoulder to the nose, the difference in length has to be quickly wound onto the bobbin. The velocity, *VR*, of the ring rail should be therefore included in Equation 6.10.

Hence,

$$N_s - N_t = [VF - VR]/\pi D_B \quad \ldots\ldots 2.11$$

when the ring rail moves up toward the nose of the cop, and

$$N_s - N_t = [V_F + V_R]/\pi D_B \quad \ldots\ldots 2.12$$

When moving downward toward the shoulder. It is evident then that N_t will vary cyclically with the movement of the ring rail. The increase in the bobbin diameter as the yarn is wound onto the bobbin will increase N_t , and this will be superimposed on the ring rail effect. Clearly, then, there will be some variation in the twist per unit length along the yarn length wound onto a bobbin. In practice, the variation is small and often falls within the random variation of measurements. Furthermore, the difference between N_s and N_t is also small, and therefore, for practical purposes, N_s is used in calculating the nominal or machine twist.

From the above discussion, it should be evident to the reader that the size of the ring diameter limits the diameter of the yarn package that can be built in ring spinning. Package size is an important factor in machine efficiency, since each time a package is changed; the spinning process is disrupted, adding to the stoppage or downtime of the spindles. In modern high-speed weaving (i.e., shuttle-less looms) and knitting processes, yarn package sizes of approximately 2.5 to 3 kg are required; therefore, the yarn packages from ring and traveler processes have to be rewound to make larger packages. However, here, it is important to point out that, when many ring-spun yarn packages are involved in making a full rewound package for subsequent processes, the quality of the fabric can be affected. This is because yarns from different spindles on a machine may vary in properties, owing to small differences in the machine elements from one spinning position to another. More detrimentally, there unknowingly may be a few incorrectly functioning spinning positions, i.e., *rogue spindles.* When the yarns from the different spindles are pieced together, they provide a continuous length on a large rewound package, and the variations in this continual length will eventually be incorporated into the fabric. If yarn from the rogue spindle is part of the pieced length, it may lead to a degrading fault in fabric. The larger the ring-yarn packages, the fewer for rewinding onto larger packages. There is also an advantage for the rewinding process, as there would be few piecings and less stoppage time to replace empty ring bobbins with full ones.

Increasing the ring diameter to produce larger cops has its limitations and disadvantages. We can see from Equations 6.8 and 6.9 that the frictional drag of the ring on the traveler increases with the square of the rotational speed of the traveler and with increased radius of the ring. Travelers are available in various forms (i.e., shape, base material and weight), but steel travelers are probably the most widely used. The frictional drag by a steel ring on a steel traveler during spinning will generate heat at the ring-traveler interface. In spite of high average temperatures (up to 300°C) being reached, the surrounding air removes only 10 to 20% of the total frictional heat by cooling; most of the heat needs to be conducted away through the ring.5 With the small contact area between the C-shaped traveler and ring, the heat can build up locally to much higher temperatures. Increased spindle speed and/or ring diameter, and thereby traveler speed, may then lead to a situation in which localized melting of the traveler occurs, and the traveler can no longer be effectively used for spinning. This is usually referred to as *traveler burn,* because, visually, the place on the traveler that makes contact with the ring becomes the blue-black color of heated metal[11].

In addition to the factor of traveler burn, there is the aspect of wear on both traveler and ring. The faster the traveler speed, the shorter the traveler life. The cautious spinner tends to quote a maximum practical speed for steel travelers to be within 35 to 40 m/s. However, research and development work by ring and traveler manufacturers, aimed at either reducing frictional wear and improving conduction of the heat generated at the ring-traveler interface, has resulted in new designs of the ring and traveler combination,6 the use of carbon rich steels, lubricated rings (oil impregnated sintered),7 and, in some cases, ceramic rings8 and special finishes. Certain developments have involved slowly rotating the ring while retaining the relative speed of the traveler. This process is called *the living ring*.9

Claims have been made for maximum traveler speed of 50 to 60 m/s.10,11 Figure 6.5 shows an example of an improved design, compared with the conventional ring-traveler geometry, and it can seen the greater surface contact would be beneficial.

We can reason from the above that increasing the yarn package size by using large diameter rings may mean reducing spindle speed and thereby production speed. Another means of increasing package size is by using a longer package length over which the yarn is wound. This is called the *lift*, and it inevitably means that the spinning position has a longer balloon height and balloon length. Two main factors, however, control the maximum balloon height: (1) balloon collapse caused by the formation of a node in the yarn balloon during spinning and (2) increased yarn tension and thereby increased interruptions of the spinning by yarn breaks (i.e., end breaks) resulting in a lower machine efficiency, ε%.

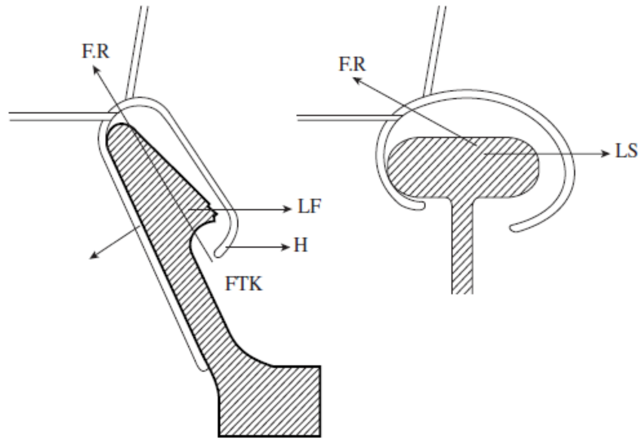


FIGURE 2.19 Orbital ring and traveler: conventional T-flange system. (Courtesy of Rieter Machine Works.)

From the simple theory of a vibrating string, it can be shown that the balloon height, *H,* balloon tension, T_B, the spindle speed, N_S, and the yarn count, C_Y , are related by

$$H = C\left\{\frac{T_B}{C_Y N_S^2}\right\}^{\frac{1}{2}} \text{ ....2.13}$$

Where C = the constant of proportionality

For a given yarn count and spindle speed, there must be a minimum balloon tension below which the balloon length, L_b, has the tendency to form a nodal point between the lappet and the traveler, resulting in balloon collapses. If we therefore wish to increase the balloon height for a given count and spindle speed, the balloon tension must be increased. However, as was stated earlier, too high a tension could result in increased end breaks and low machine efficiency. Since the traveler is pulled around the ring circumference by the yarn, the drag of the traveler mass, M, influences the tension in the yarn. Also, if H is large, the required M could result in a spinning tension greater than the strength of the yarn being spun. To circumvent the use of too heavy a traveler, balloon control rings (see Figure 6.3) are used to prevent a nodal point from forming in the balloon profile. The lightest traveler mass, M, for a given balloon height, yarn count, and ring diameter D_R is given by

$$M = \frac{KH^2C_Y}{D_R} \text{ ....2.14}$$

where K = the constant of proportionality

With medium to coarse count yarns, say 40 to 100 tex, building sizeable packages requires the use of a balloon control ring. For very coarse counts, such as in the area of carpet yarns, it becomes necessary to spin with a collapsed balloon in order to produce a useful size spinning package for rewinding. See Figure 6.6. As the figure shows, the yarn balloon length partially wraps around the spindle, but such coarse yarns have sufficient strength to overcome the frictional drag of the spindle without breaking. The frictional contact with the spindle will resist the twist propagation toward the front drafting rollers; this is additional to the effect of the lappet. A false-twisting device fitted on the end of the spindle is therefore used to prevent spinning beaks because of low twist reaching the spinning triangle[11].

2.4.4 Key Points

Generally, ring and traveler systems have the following technical advantages and disadvantages.

Advantages

• They offer a wide spinning count range, e.g., 5 to 300 tex.

• They provide the ability to process most natural and man-made fibers and fiber blends.

• They produce staple yarns of tensile strength and handling aesthetics suitable for the majority of fabric end uses. The properties of ring-spun yarns are therefore used as a standard against which new yarns are compared.

Disadvantages

• Even in the ideal situation of no end breaks, spinning is still discontinuous, because it has to be interrupted for doffing.

• To attain high twisting rates and thereby high production speed, the yarn package must be reduced in size, resulting in frequent stoppages for doffing.

• The maximum mechanical speed is restricted by the frictional contact of ring and traveler and yarn tension.

• Bobbin size is restricted by the ring diameter.

• Yarn has to be rewound to produce larger size packages

• Usually, the preparatory processes have to include roving production; spinning from sliver would be more economical.

It is important to note that the first four of the above limitations arise because, in ring spinning, twisting and winding of the yarn onto a bobbin are combined in the one action of the traveler being pulled around the ring.

The alternative spinning methods listed in Table 3.1 enable twisting and package building to occur as separate, simultaneous actions. Some of these methods retain twist in the spun yarn. With others, the twisting action is a temporary means of imparting integrity to the attenuated fiber mass forming the yarn bulk while this mass is either helically wrapped with a filament or staple fibers or bonded chemically or mechanically to obtained final integrity and strength. By separating twisting from package building, larger size packages can be made but, importantly, higher twisting rates also can be achieved to give faster production speeds as Figure 3.2 shows[11].

CHAPTER THREE

PRODUCT PLANNING

3.1 Degree of Novelty of a Product

The tasks of designers can have different degrees of novelty. The majority of tasks are adaptations to and variations on existing designs. This does not imply that these tasks are less challenging for designers. For product planning, the following differentiation of design tasks is of interest:

- ***Original design:*** New tasks and problems are solved using new or novel combinations of known solution principles. Two different cases can be distinguished:
  1. An invention is something truly new and is often based on the application of the latest scientific knowledge and insights.
  2. An innovation is a product that realizes new functions and properties. This could be through novel or new combinations of existing solutions.
- ***Adaptive design****:* The solution principle remains unchanged; only the embodiment is adapted to new requirements and constraints.
- ***Variant design****:* The sizes and arrangements of parts and assemblies are varied within the limits set by previously designed product structures, which is typical of size ranges and modular products.

In this thesis work combination of the above design tasks/problem solving methods will be applied. Original design mechanism will be involved at some part of the machine and adaptive design and variant design will applied from the modern spinning machines, small scale spinning machine and improved yarn winding machine mechanisms.

3.2 Product Life Cycle

Every product has a life cycle as illustrated in Figure 3.1. This is based on an economic viewpoint showing turnover, as well as profit and loss. The *cycle time* depends strongly on the type of product and the branch of engineering, but in general cycles times are becoming shorter. This trend is likely to continue. This has a large effect on work in the design and development department because the time allocated for tasks that are identical, or very similar, to previous ones is reduced.

Measures to reactivate the market or generate new products have to be introduced when the saturation phase has been reached, at the latest. The introduction of these measures is an important task of product monitoring. A related activity in this context is the development of *market share*.

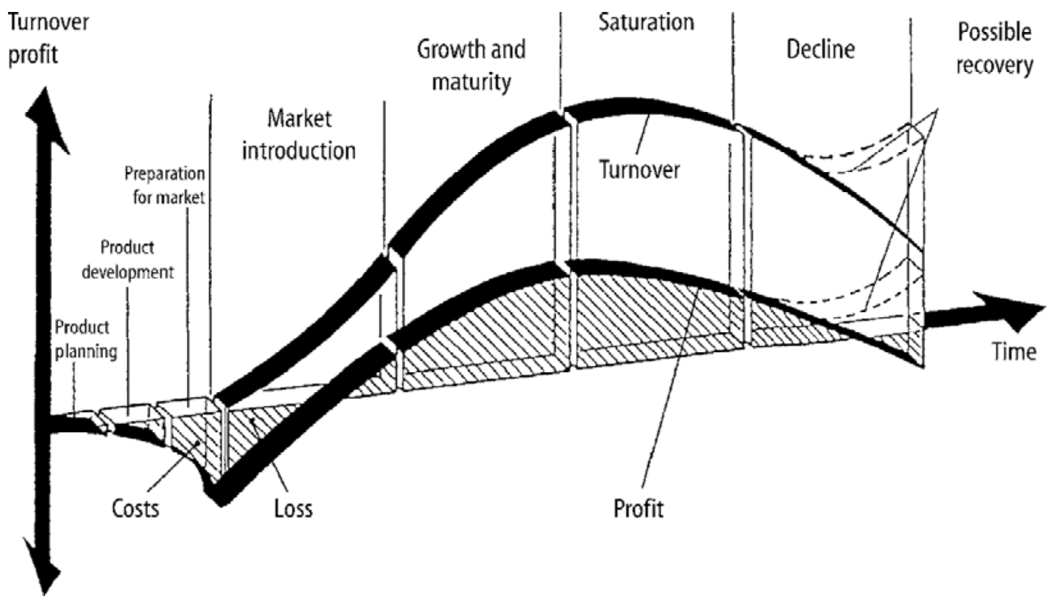


Figure 3.1 Product life cycle

➢ Product description:

✓ The machine will be manually or motor operated cotton spinning machines. In Ethiopia traditional hand spun yarn clothes are very attractive and needed by the community therefore this machine will be designed so that it can produce mainly similar yarn with the hand spun yarn.

➢ Key business Goals:

The main goal of every company is to make a profit. This goal has to be broken down into more concrete sub goals and related measures. To secure a lasting market presence, two generic strategies can be distinguished. The first strategy aims at achieving cost leadership. The corresponding company goals and implementation strategies are a broad sales base, large volumes, and rigorous product standardization. The second strategy is that of performance differentiation. In this case, the goals and strategies focus on sales in special areas, highly effective flexible production, and specialization in design and development. Both strategies have a time component, which is reflected in the company goal of being quicker to reach the market with a new product than its competitors.

One extreme strategy combines both strategies mentioned above, which, due to increasing competition, is becoming increasingly important.

Both of these goals cost leadership and performance differentiation affect the design and development department. At the next level down, many detailed goals are established, including those relating to the:

- ***Product**:* Such as functionality and properties
- ***Market**:* Such as time-to-market, which influences the time and budget made available

It is therefore very important for the design and development department to know the company's goals, their interrelationship and their relative importance. Based on these the main goals of the project will be to design a spinning machine to:

- ✓ Disseminate and spread appropriate technology to the country
- ✓ Create job opportunity
- ✓ Support the weavers and different communities to utilize cotton, their work force and time effectively
- ✓ Serve as plat form for all spinning products and solution
- ✓ Capture most of the spinning and winding machine sales in primary market in Ethiopia
- ✓ Encourage the small and middle scale industries in the country

➢ Primary market:

Weavers organized in micro and small scale enterprises in towns and in rural area, middle scale enterprises and investors working in weaving

➢ Secondary market:

- ✓ Weavers working individually home to home
- ✓ Groups and Individuals who needs to work spinning and winding jobs.

➢ Assumptions and constraints:

- ✓ Manually or motor operated
- ✓ Compatible for small and middle scale weaver enterprises
- ✓ Can be manufactured in Ethiopia
- ✓ Will spin only processed cotton in industry

- Stake holders:
  - ✓ Weavers in micro and small scale enterprises and individual weavers
  - ✓ Weaving product sellers and distributers and users
  - ✓ Manufacturing enterprises and industries
  - ✓ Government specially in textile sector
  - ✓ Distributors and resellers of the machine

3.3 Customer Needs Process

Most important for determining search fields is the identification of customer needs and market trends. Clues for these come from changes in customer behavior caused, for example, by social developments such as environmental awareness, disposal problems, reduction in the working week, and transport problems. Another starting point could be changes in the length of the production supply chain, which can lead to new markets for suppliers.

Identifying customer needs is itself a process, for which we present a five-step method. We believe that a little structure goes a long way in facilitating effective product development practices, and we hope and expect that this method will be viewed by those who employ it not as a rigid process but rather as a starting point for continuous improvement and refinement. The five steps are:

1. Gather raw data from customer
2. Interpret the raw data in terms of customer needs
3. Organize the needs into a hierarchy of primary, secondary and (if necessary) tertiary needs
4. Establish the relative importance of the needs
5. Reflect on the result and the process

3.4 Gathering Raw Data

During analyzing the customer need process, raw data should be gathered by the following methods

- Interviews
- Focus group
- Observing the product in use

Regarding the cotton spinning machine, we ask the weavers the following questions to help us know what their need is.

- When and why do they use the hand spun yarn?
- What types of spinning machine are they using?
- What is the amount of the yarn they can produce per day?
- What do they like about the hand spun yarn?
- What do they dislike about the hand spun yarn?
- What do they like about their spinning mechanism?
- What do they dislike about their spinning mechanism?
- What issues do they consider when buying and using the hand spun yarn?
- Their wishes about spinning machine and hand spun yarn?

Similarly regarding the yarn winding machine, we ask the weavers the following questions to help us know what their need is.

- When and why do they use the yarn winding machine?
- What types of winding mechanism are they using?
- What type of spindles are they using
- What is the amount of the yarn they can wind per day?
- What do they like about their winding system?
- What do they dislike about their winding system?
- What issues do they consider winding yarn?
- Their wishes about winding machine and winded yarn on the spindle?

3.5 Interpreting Data

While interpreting the data the following guidelines are considered

- Express the need in terms of what the product has to do, not in terms of how it might do
- Express the need as specifically as the raw data
- Use positive not negative phrasing
- Express the need as an attribute of the product
- Avoid the words 'must' and 'should'

Based on the above questions and guidelines, data were gathered from the customers and interpreted as follows.

- The spinning machine will spine cotton
- The spinning machine is light weight
- The spinning machine is easily drive and rotate able
- The spinning machine can spine processed cotton installed in $6m^2$ area
- Maximum driving and spinning power is 1hp
- Can spine upto eighteen spools at the same time
- The spinning machine is portable and compatible for micro and small scale and middle scale operators

Now at this phase we can have as many as possible need statements of the spinning machine. From these need statements we can develop one problem statement which describes the overall idea of the need statements and it is more detailed one.

CHAPTER FOUR

CONCEPTUAL DESIGN

Conceptual design is the part of the design process where-by identifying the essential problems through abstraction, establishing function structures, searching for appropriate working principles and combining these in to a working structure the basic solution path is laid down through the elaboration of a solution principle. Conceptual design *specifies the principle solution*.

In this phase the needs of the target market are identified, alternative product concepts are generated and evaluated, and one or more concepts are selected for further development and testing. A concept is a description of the form, function, and features of a product and is usually accompanied by a set of specifications, an analysis of competitive products, and an economic justification of the project.

4.1 Conceptual Design Definition

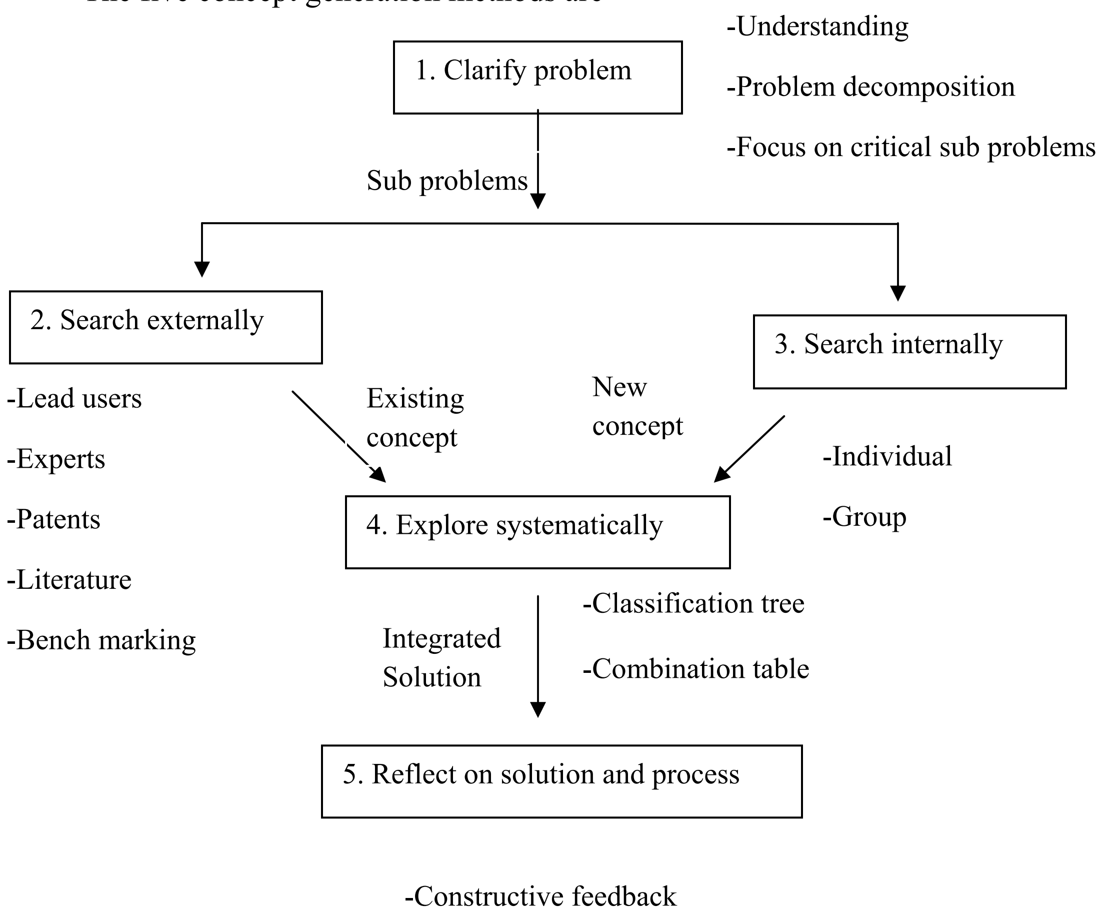
Conceptual design is that part of design process in which, by the identification of essential problems through abstraction, by establishment function structures and by the search for appropriate solution principles and their combination, the basic solution path is laid through the elaboration of solution concept.

In the conceptual design phase we should ask the following questions to start with,

- What existing solution concepts are available and productive
- What existing solution concepts could be successfully adapted for this application?
- What new concept might satisfy the establishment needs and specifications?
- What methods can be used to facilitate the concept generation process?

4.2 Concept Generation Methods

The five concept generation methods are



4.3 Clarifying Objectives

Aim: to clarify design objectives and sub-objectives, and the relationship between them. A design has to start from some basic information when confronted with the design task. Sources of the information the data gathered and analyzed from customer or an invention proposition.

4.4 Statement of the Problem for the Cotton Spinning Machine

It is required to design a spinning machines operated manually and by motor, that can spin cotton on about eighteen spools simultaneously with a better quality than the traditional spinning. It should be light weight and easily portable. It is easily drive and rotate able with energy consumption of maximum up to 1hp of motor operated machine.

The cruxes of the design are:

- to improve the technical functions
- to reduce weight and space
- to significantly lower costs
- to improve production methods.

4.5 Analyzing the function

The operational principle of the spinning machine is that the processed cotton is placed as an input on the right and left side of the machine. This cotton will be feed to the roving and drafting systems. In this system the cotton will be drawn. The drawn cotton then pass through the hole of spindle shaft (lappet) which will introduce a false twist.

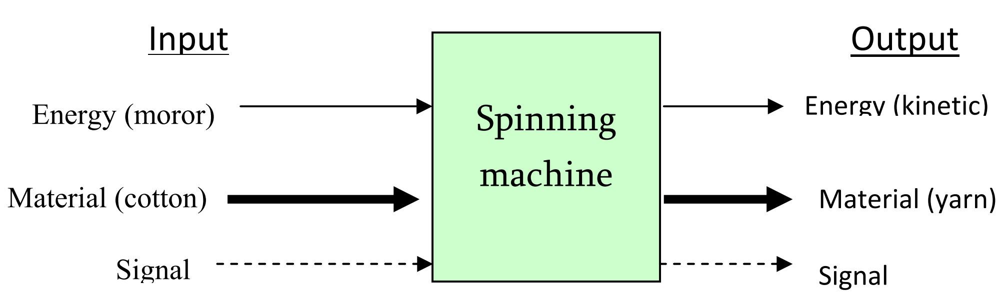
The spindle shaft is produced from a hallow shaft and some distance from the end there will be radial hole to the axis of the shaft. The spinning part has five main components: arm, ring, ring slot, ring rail (building controller). First spool is inserted in the spool shaft, and then the arm holding the ring slot and the ring will be inserted in the spool shaft.

The drawn cotton then pass through hallow of the spindle shaft and exit through the radial hole. Then the cotton will pass through the arm hole to the ring and finally started to the spool. The spool and the ring rotational speed is different this creates spinning and winding of the yarn on the spool simultaneously.

The drive system will get power from motor. Gear and pulley mechanisms will be provided to drive the all the spinning, roving and rolling parts of the machine.

- **Break Down of Tasks in to Functions**

Here we analyze the main function of the fertilizer distributor with the input and output diagram.



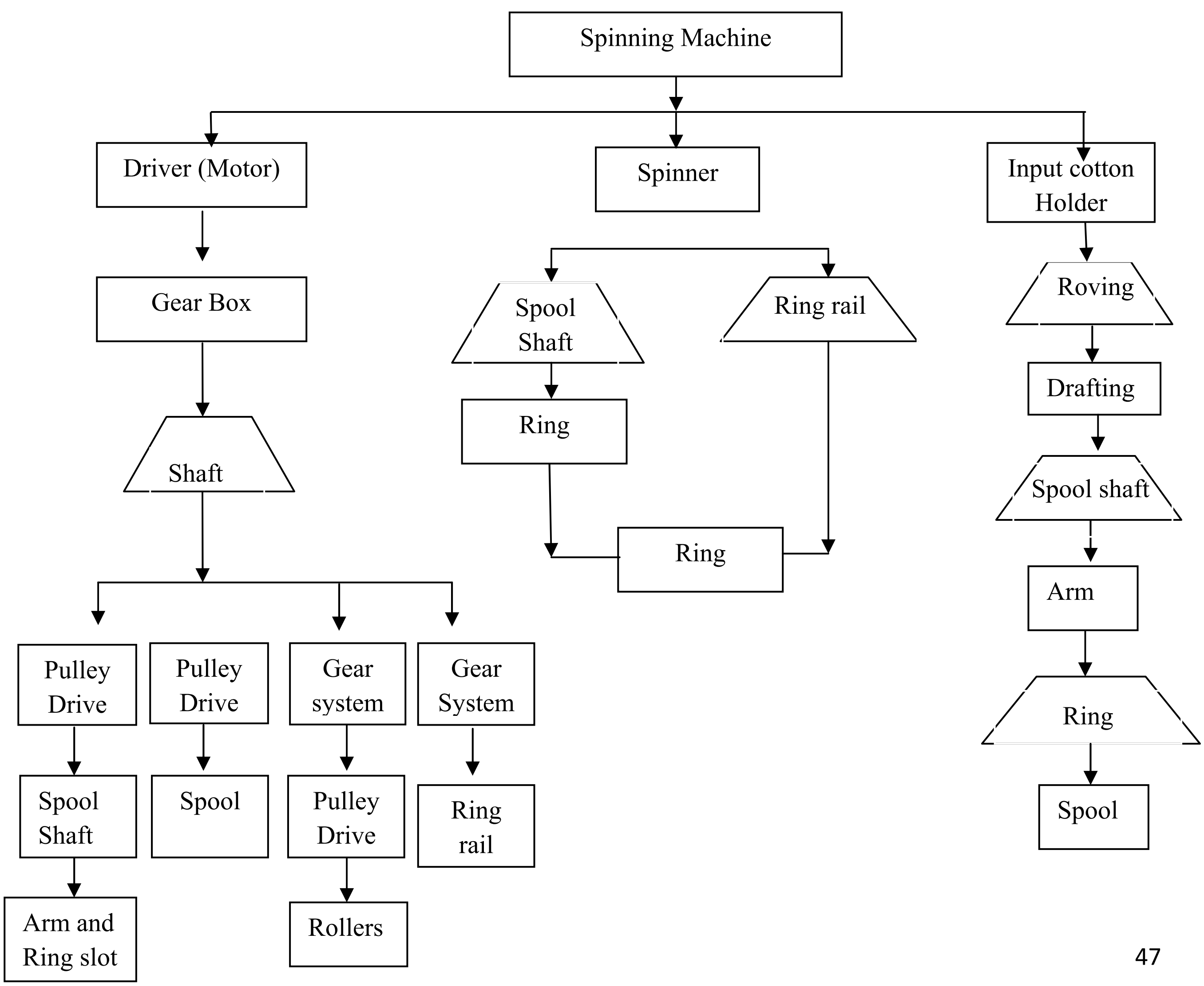
4.6 Function Means Tree

Depending on the complexity of the problem, the resulting overall function will in turn be more or less complex. By complexity mean the relative lack of transparency of relationships between inputs and outputs, the relative intricacy of the necessary physical processes, and the relatively large number of assemblies and components involved.

The object of breaking down complex function is:

- The determination of sub-functions facilitating the subsequent search for solutions; and
- The combination of these sub-functions in to a simple and unambiguous function structure.

Hence by further analyzing the function of the spinning machine we can divide the main function of the spinning machine into sub functions and we can determine the means for these sub functions.



Generating Alternatives

Aim: to generate the complete range of alternatives design solutions for a product, and hence to widen the search for potential new solutions.

Of course this is achieved by analyzing the functions and means that we have established in the previous section. Here we should think exhaustively what possible solution we might get to achieve every sub functions of the distributer. As a result we get number of design alternatives of spinning machine from modern to traditional mechanisms. Then this machine will be designed by taking mechanisms from the traditional and modern spinning machine systems. The following figures shows, ring spinning mechanism from the modern spinning system and spinning wheel from the tradition spinning system.

Figure 4.1 Ring spinning machine with its driving mechanism

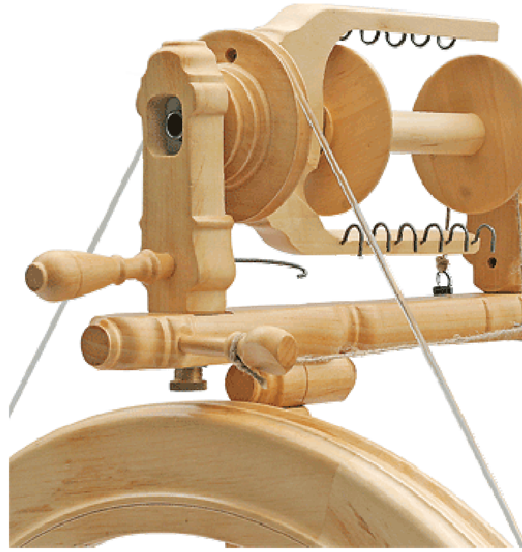



Figure 4.2 spinning wheel

4.7 Determination of Weighting Factor

When many design criteria's are used to specify the degree of importance of each, it may be difficult to re-establish weighting factors. One way to do so is to use a digital logic approach. Each property is compared in every combination taken at a time. To make the comparison, the property that is considered to be the more important of the two is given a "one" and the less important a "zero", the total number of properties under consideration is:

$$N = n(n-1)/2 \quad \ldots\ldots 4.1$$

Where N- the total number of possible comparison pairs.

n- the total number of criteria

w_i - The weighting factor = m_i /N

Where $\mathbf{m_i}$ the total number of positive decisions for the i^{th} criteria

Now using this principle we can apply for the listed design alternative to select the best one.

4.8 Evaluating Alternatives

In order to make any kind of evaluation, it is necessary to have a set of criteria and these must be based on the design objectives. i.e. what it is that design is meant to achieve. The objective will include technical and economical factors, user requirements and so on. Hence the following objectives are chosen to evaluate the design characteristic of each feature.

Cost, performance, reliability, availability, maintainability, power, ergonomics

We may have the same or different evaluating criteria, which depend on the type of features to be evaluated as well as the amount of dependency if it affects adversely, we could use as a measuring criteria for that feature. The type and number of criteria are determined by individual judgment. There are no proper set of rules for setting design criteria, since it depends on the type and application of design and its complication.

4.9 Selection Criteria

The first step in any evaluation is the drawing up of set objectives from which evaluation criteria can be derived. In the technical field, such objectives are mainly based on the requirements of the specification and on the general constraints.

Evaluation criteria can be directly derived from the objectives. Because of the subsequent assignment values and given a positive formulation. Use value analysis systematizes this step by means of an objective tree, in which the individual objectives are arranged in hierarchy order.

The general selection criteria to be considered are:

1. Ease of handling
2. Ease of use
3. Ease of operation
4. Durability
5. Productivity/Efficiency
6. Ease of manufacture
7. Portability
8. Ease of maintenance
9. Low wear of moving parts
10. Low susceptibility of vibration
11. Few disturbing factors
12. Small number of components
13. Low complexity of components
14. Many standards and bought out parts
15. Simple assembly
16. Low cost

4.11 Weighting evaluation criteria

To establish evaluation criteria, we must first assess their relative contribution (weighting) to the overall value of the solution, so that relatively unimportant criteria can be eliminated before the evaluation properly begins. The evaluation criteria retained are given 'weighting factors' which must be taken into consideration during the subsequent evaluation step. Weighting factor is real, positive number. It indicates the relative importance of particular evaluation criterion (objective).

N = n (n-1)/2
If n = 15, N = 16 (16-1)/2 = 120

Table 4.1 Determination of weighting factor for selection of arrangement of spinning Machine

Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	m_i	w_i
1	**x**	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2	0.02
2	1	**x**	0	0	0	1	1	0	0	0	1	1	0	0	0	1	6	0.05
3	1	1	**X**	0	0	0	1	0	0	0	1	0	1	1	0	1	7	0.06
4	1	1	1	**x**	0	1	0	0	1	1	0	0	0	0	0	1	7	0.06
5	1	1	1	1	**x**	1	1	0	0	1	1	1	0	1	1	1	12	0.1
6	0	0	1	0	0	**X**	0	0	1	0	0	0	1	0	1	1	5	0.04
7	0	0	0	1	0	1	**x**	1	0	0	0	1	0	1	1	1	7	0.06
8	1	1	1	1	1	1	0	**x**	0	0	1	0	0	0	1	0	8	0.07
9	1	1	1	0	1	0	1	1	**x**	1	0	0	1	1	0	1	10	0.08
10	1	1	1	0	0	1	1	1	0	**x**	1	1	0	0	1	1	10	0.08
11	1	0	0	1	1	1	1	0	1	0	**x**	0	0	0	1	1	8	0.07
12	1	0	1	1	0	1	0	1	1	0	1	**x**	0	1	1	1	10	0.08
13	1	1	0	1	1	0	1	1	0	0	1	1	**x**	0	1	1	10	0.08
14	1	1	0	1	0	1	0	1	0	1	1	0	1	**x**	1	1	9	0.08
15	1	1	1	1	0	0	0	0	1	0	0	0	0	0	**x**	1	6	0.05
16	1	0	0	1		0	0	1	0	0	0	0	0	0	0	**x**	2	0.02

1. The Driving Power System Selection

There are different power system choices in order to drive the spinning machine as explained above. These are manually operated and electric motor operated spinning machine.

Criteria for Evaluation

1. Ease of Design
2. Ease of Assembly
3. Ease of Manufacturing
4. Efficiency
5. Productivity
6. Compact/ Light weight
7. Easy of operation
8. Low cost

N = n (n-1)/2

If n = 8, N = 28

Table 4.2

Criteria	1	2	3	4	5	6	7	8	m_i	w_i
1	**x**	0	0	0	1	0	0	0	1	0.036
2	1	**x**	0	0	1	0	0	1	3	0.107
3	1	1	**x**	0	0	0	0	1	3	0.107
4	1	1	1	**x**	1	1	1	1	7	0.25
5	0	0	1	0	**x**	0	1	1	3	0.107
6	1	1	1	0	1	**x**	1	1	6	0.214
7	1	1	1	0	0	0	**x**	1	4	0.143
8	1	0	0		0	0	0	**x**	1	0.036

Table 4.3 Selection of Power driving system

Design Criteria	1	2	3	4	5	6	7	8	Sum W*V
Weighting Factor	0.036	0.107	0.107	0.25	0.107	0.21	0.143	0.036	
Design of Motor driven	97	100	100	98	100	97	95	94	
V*w	3.492	10.7	10.7	24.5	10.7	20.8	13.59	3.384	**97.819**
Design of Manual Driven	94	95	92	90	100	95	**99**	100	
V*w	3.384	10.17	9.844	22.5	10.7	20.3	14.16	3.6	**91.08**

Therefore motor driven is selected

2. **Spinning System Selection**

There are different types of spinning mechanisms but the main systems are grouped in two ring spinning and open end spinning. The following criteria can be used to select from these two groups of spinning systems.

1. Offer a wide spinning count range
2. Process most natural and man-made fibers and fiber blends.
3. Compatibility to combine with the small scale machine
4. Ease of operation
5. Productivity/Efficiency
6. Ease of manufacture
7. Ease of maintenance
8. Small number of components
9. Low complexity of components
10. Simple assembly
11. Low cost

N = n (n-1)/2 Where n = 11 N = 11(11 - 1)/2 = 55

Table 4.4

Criteria	1	2	3	4	5	6	7	8	9	10	11	m_i	w_i
1	**x**	1	0	1	0	0	1	1	0	1	1	6	0.10909
2	0	**x**	0	1	0	1	1	1	0	1	0	5	0.09091
3	1	1	**x**	1	1	0	1	1	0	1	0	7	0.12727
4	0	0	0	**x**	0	0	0	0	1	0	1	2	0.03636
5	1	1	0	1	**x**	1	0	1	0	1	1	7	0.12727
6	1	0	1	1	0	**x**	0	0	1	1	1	6	0.10909
7	0	0	0	1	1	1	**x**	0	0	1	0	4	0.07273
8	0	0	0	1	0	1	1	**x**	0	1	1	5	0.09091
9	1	1	1	0	1	0	1	1	**x**	1	1	8	0.14545
10	0	0	0	1	0	0	0	0	0	**x**	1	2	0.03636
11	0	1	1	0	0	0	1	0	0	0	**x**	3	0.05455

Table 4.5 Selection of spinning system

Design Criteria	1	2	3	4	5	6	7	8	9	10	11	Sum W*V
Weighting Factor	0.109	0.091	0.127	0.036	0.127	0.109	0.073	0.091	0.145	0.036	0.055	
Design of ring spinning	100	100	100	98	90	97	98	97	98	96	97	
V*w	10.91	9.091	12.73	3.56	11.5	10.6	7.13	8.818	14.3	3.491	5.291	**97.3**
Design of Open end spinning	94	95	92	90	100	90	92	95	90	**90**	**91**	
V*w	10.25	8.636	11.71	3.27	12.7	9.82	6.69	8.636	13.1	3.273	4.964	**93.1**

Therefore ring spinning is selected

3. Spindle Shaft Arrangement Mechanism

The spindle shafts can be arranged: vertically or horizontally based on the following criteria one of the arrangements will be selected.

1. Ease of handling
2. Ease of use
3. Ease of operation
4. Productivity/Efficiency
5. Ease of manufacture
6. Portability
7. Ease of maintenance
8. Small number of components
9. Low complexity of components
10. Simple assembly
11. Low cost

N = n (n-1)/2 Where **n = 11** N = 11(11 - 1)/2 = 55

Table 4.6

Criteria	1	2	3	4	5	6	7	8	9	10	11	m_i	w_i
1	**x**	0	0	0	1	1	0	0	0	0	0	2	0.0364
2	1	**x**	0	0	1	1	0	1	0	0	1	5	0.0909
3	1	1	**x**	0	0	1	0	0	1	0	1	5	0.0909
4	1	1	1	**x**	1	1	0	1	0	1	1	8	0.1455
5	0	0	1	0	**x**	0	0	0	1	1	1	4	0.0727
6	0	0	0	0	1	**x**	1	1	0	1	1	5	0.0909
7	1	1	1	1	1	0	**x**	0	0	1	0	6	0.1091
8	1	0	1	0	1	0	1	**x**	0	1	1	6	0.1091
9	1	1	0	1	0	1	1	1	**x**	1	1	8	0.1455
10	1	1	1	0	0	0	0	0	0	**x**	1	4	0.0727
11	1	0	0	0	0	0	1	0	0	0	**x**	2	0.0364

Table 4.7 Selection of spindle shaft arrangement

Design Criteria	1	2	3	4	5	6	7	8	9	10	11	Sum W*V
Weighting Factor	0.036	0.091	0.091	0.145	0.07	0.091	0.109	0.11	0.145	0.07	0.036	
Design of Vertical arrangement	92	90	94	90	95	97	94	92	91	96	92	
V*w	3.345	8.18	8.545	13.09	6.91	8.82	10.3	10	13.2	6.98	3.345	**92.745**
Design of Horizontal arrangement	98	97	100	99	97	98	98	99	98	98	91	
V*w	3.564	8.82	9.091	14.4	7.06	8.91	10.7	10.8	14.3	7.13	3.309	**98.018**

Therefore horizontal arrangement is selected

4. **Power Transmission and Speed Reducer System Selection**

There are different Power Transmission and speed reducer system choices in order to drive the spinning machine as explained above. These are belt drive transmission system and gear transmission.

Criteria for Evaluation

1. Ease of handling
2. Ease of use
3. Ease of operation
4. Ease of manufacture
5. Ease of maintenance
6. Low susceptibility of vibration
7. Low complexity of components
8. Simple assembly
9. Low cost

N = n (n-1)/2   If n = 9, N = 36

Table 4.8

Criteria	1	2	3	4	5	6	7	8	9	m_i	w_i
1	**x**	0	0	1	0	0	0	0	0	1	0.0278
2	1	**X**	0	1	0	0	0	0	1	3	0.0833
3	1	1	**x**	0	0	0	1	0	1	4	0.1111
4	0	0	1	**x**	0	0	1	1	1	4	0.1111
5	1	1	1	1	**x**	0	0	1	0	5	0.1389
6	1	1	1	1	1	**x**	0	1	1	7	0.1944
7	1	1	0	0	1	0	**x**	1	1	5	0.1389
8	1	1	1	0	0	0	0	**x**	1	4	0.1111
9	1	0	0	0	1	0	0	0	**x**	2	0.0556

Table 4.9 Selection of Power Transmission and speed reducer system

Design Criteria	1	2	3	4	5	6	7	8	9	sum of v*w
Weighting Factor	0	0.1	0.1	0.1	0.14	0.19	0.1	0.11	0.1	
belt	98	99	100	100	100	98	100	100	98	
V*w	2.7	8.3	11	11	13.9	19	14	11	5.4	96.58
gear	92	94	90	95	94	94	95	94	92	
V*w	2.6	7.8	10	11	13.1	18	13	10	5.1	91.02

Therefore belt is selected

5. **Belt Drive Selection**

To transmit power from the motor to shaft we can select a belt among the following belt types

A. Flat belt

B. Timing

C. Round

D. V-belt

Selection criteria

1. Noiselessness
2. Less Torsional vibration
3. Good transmitting power
4. Good maintenance

N = n (n-1)/2 If n = 4, N = 6

Table 4.10

Criteria	1	2	3	4	m_i	w_i
2	1	**x**	1	0	2	0.33
3	1	1	**x**	1	3	0.5
4	0	1	0	**x**	1	0.33

Table 4.11 Selection for Belt

Design Criteria	1	2	3	4	Sum W*V
Weighting Factor	0.167	0.333	0.5	0.167	
Design of Timing belt	87	87	80	92	
V*w	14.529	28.97	40	15.364	98.863
Design of V-belt	85	80	79	90	
V*w	14.529	26.64	39.5	15.03	95.699
Design of round	80	85	80	90	
V*w	13.36	28.305	40	15.03	96.695
Design of Flat belt	88	87	81	93	
V*w	14.696	28.97	40.5	15.531	99.697

Therefore flat belt is selected

6. Rotation Plane Changing Mechanism from Shaft to Roller Rotation Plane

To change the rotation plane of the shaft to rotation plane of rollers we can use worm gear or bevel gear mechanism based on the following selecting criteria.

1. Ease of Use
2. Ease of operation
3. Durability
4. Ease of Manufacturing
5. Low wear of moving parts
6. Few disturbing factors
7. Simple assembly
8. Low cost

Table 4.12

Criteria	2	3	4	6	9	11	15	16	m_i	w_i
1	**x**	0	0	1	0	1	0	1	3	0.10714
2	1	**x**	0	0	0	1	0	1	3	0.10714
3	1	1	**x**	1	1	0	0	1	5	0.17857
4	0	1	0	**x**	1	0	1	1	4	0.14286
5	1	1	0	0	**X**	0	0	1	3	0.10714
6	0	0	1	1	1	**x**	1	1	5	0.17857
7	1	1	1	0	1	0	**x**	1	5	0.17857
8	0	0	1	0	0	0	0	**x**	1	0.03571

Table 4.13 Selection Of Rotation Plane Changing Mechanism

Design Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Sum W*V**
Weighting Factor	0.11	0.11	0.18	0.14	0.11	0.18	0.18	0.04	
bevel gear	95	96	98	96	96	97	96	95	
V*w	10.2	10.3	17.5	13.7	10.3	17.3	17.1	3.39	**99.82**
wormgear	96	95	92	96	96	95	**94**	92	
V*w	10.3	10.2	16.4	13.7	10.3	17	16.8	3.29	**97.93**

Therefore bevel gear is selected.

7. **Driving Mechanism for Yarn Building Controller**

To drive and govern the yarn building controller it needs to change plane of rotation and high speed reduction ratio. Warm gear and bavel gear can be seen as choice for this purpose. Based on the criteria seen in the above section we can select as follows.

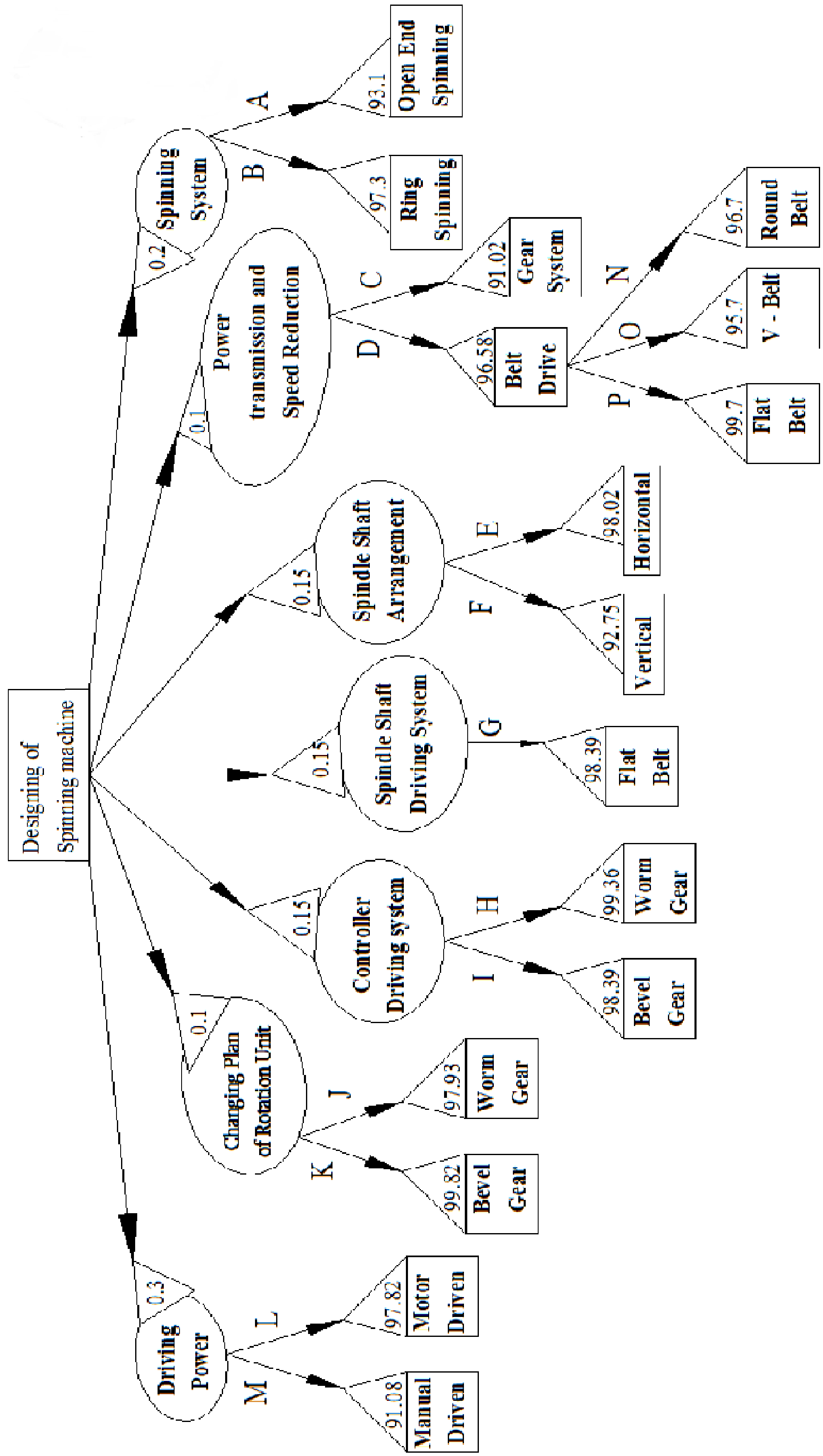
Table 4.14

Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**m_i**	**w_i**
1	**x**	0	0	1	0	1	0	1	3	0.10714
2	1	**x**	0	0	0	1	0	1	3	0.10714
3	1	1	**x**	1	1	0	0	1	5	0.17857
4	0	1	0	**x**	1	0	1	1	4	0.14286
5	1	1	0	0	**X**	0	0	1	3	0.10714
6	0	0	1	1	1	**x**	1	1	5	0.17857
7	1	1	1	0	1	0	**x**	1	5	0.17857
8	0	0	1	0	0	0	0	**x**	1	0.03571

Table 4.15 Selection of driving mechanism for yarn building controller

Design Criteria	1	2	3	4	5	6	7	8	Sum W*V
Weighting Factor	0.107	0.107	0.179	0.143	0.107	0.179	0.179	0.036	
Bevel gear	95	96	90	96	96	97	96	95	
V*w	10.18	10.29	16.07	13.71	10.29	17.32	17.14	3.393	**98.39**
Worm gear	96	95	100	96	96	95	**94**	92	
V*w	10.29	10.18	17.86	13.71	10.29	16.96	16.79	3.286	**99.36**

Therefore worm gear is selected


Designing of Spinning machine
Spinning System
0.2
A
93.1
Open End Spinning
B
97.3
Ring Spinning
Power transmission and Speed Reduction
0.1
C
91.02
Gear System
D
96.58
Belt Drive
N
96.7
Round Belt
O
95.7
V - Belt
P
99.7
Flat Belt
Spindle Shaft Arrangement
0.15
E
98.02
Horizontal
F
92.75
Vertical
Spindle Shaft Driving System
0.15
G
98.39
Flat Belt
Controller Driving system
0.15
H
99.36
Worm Gear
I
98.39
Bevel Gear
Changing Plan of Rotation Unit
0.1
J
97.93
Worm Gear
K
99.82
Bevel Gear
Driving Power
0.3
L
97.82
Motor Driven
M
91.08
Manual Driven

CHAPTER FIVE

SYSTEM-LEVEL AND EMBODIMENT DESIGN

The system-level design phase includes the definition of the product architecture and the decomposition of the product into subsystems and components. The final assembly scheme for the production system is usually defined during this phase as well. The output of this phase usually includes a geometric layout of the product, a functional specification of each of the product's subsystems, and a preliminary process flow diagram for the final assembly process.

5.1 Product Architecture

The architecture and arrangement of the spinning machine is shown on the figure below the spinning part is found at the middle of the machine. In both right and left sides rollers and processed cotton will be placed. The driving motor and shaft with different pulley and gear arrangements are fitted at the bottom to drive the spindle shafts, rollers and rings.

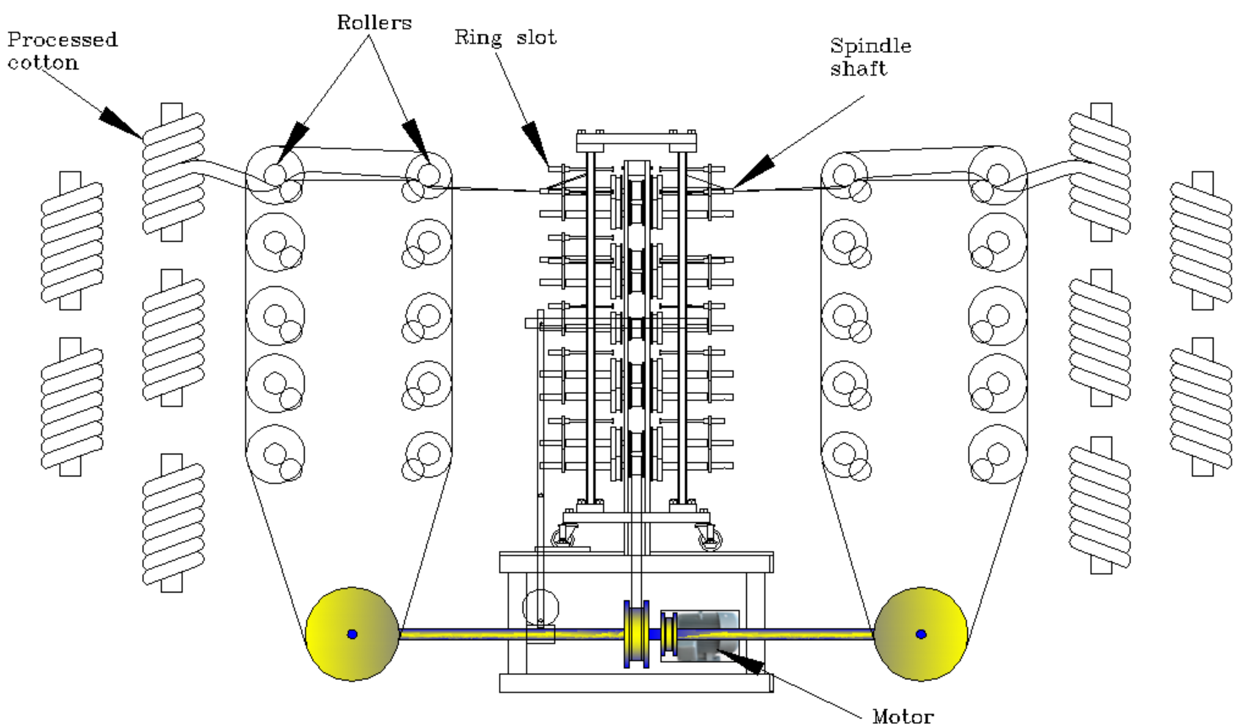


Figure 5.1 Product architecture

5.2 Components and Sub Assemblies

The main components of the machine are listed as follows

1. Spindle shaft
2. Spindle shaft pulley
3. Traveler
4. Traveler slot
5. Slot arm
6. Spool/cop/bobbin
7. Traveler guide
8. Rollers
9. Guid arm
10. Input holder
11. Motor
12. Motor pulley
13. Main shaft
14. Pulley 1
15. Pulley 2
16. Pulley 3
17. Pulley 4
18. Pulley 5
19. Pulley 6
20. Pulley 7
21. Warm gear
22. Bevel Gear
23. Belt 1
24. Belt 2
25. Belt 3
26. Belt 4

5.2.2 Spinning Part

5.2.2.1 ***Spindle shaft: -*** is the rotating element holding the spindle to twist, spin and wind the yarn. It is driven by power from the motor transmitted through pulleys.

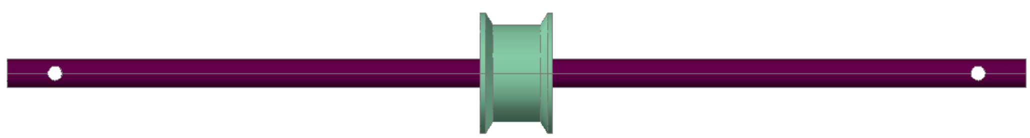


Figure 5.2 Spindle shaft

5.2.2.2 ***Traveler and Traveler slot: -*** The traveler is moving axially and revolves around the spindle shaft with the slot holding yarn to create twisting and winding the yarn. The slot is used to hold the ring inside it.

Figure 5.3 Traveler and Traveler slot

5.2.2.3 ***Slot Arm and Spool/Bobbin:-*** The slot arm is used to connect the spindle shaft and revolve slot around the spindle. The bobbin is the component on which the spanned yarn is placed winded. It has head with belt groove.

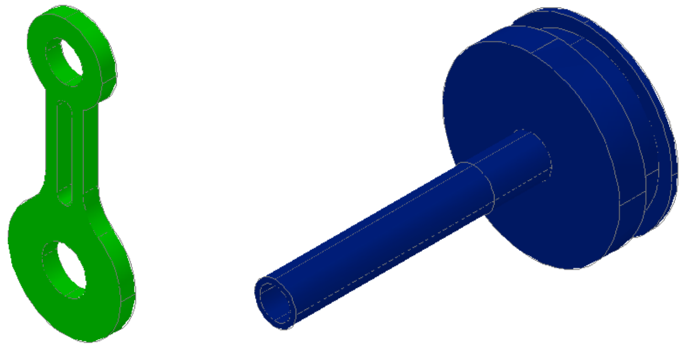
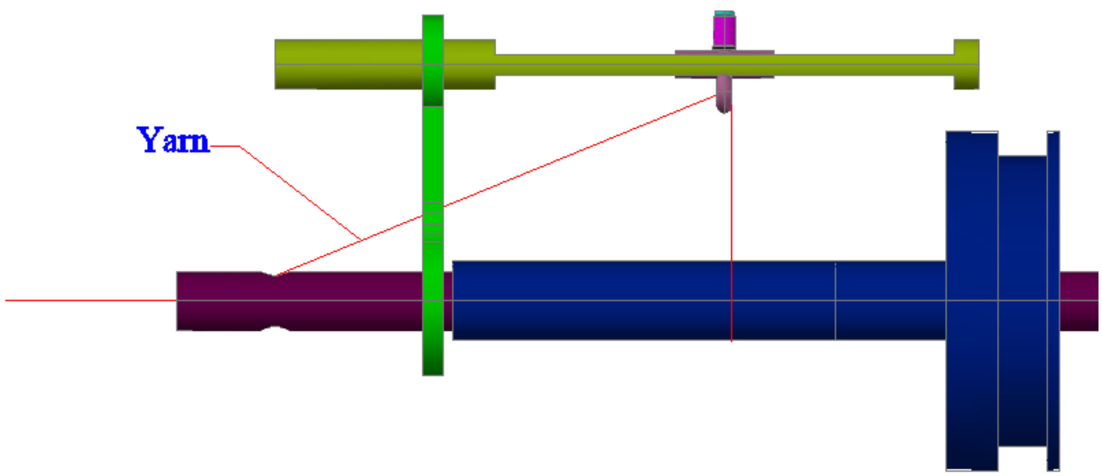


Figure 5.4 Slot Arm and Bobbin

The assembly of the spinning part shows the spool fitted in the spindle shaft. The arm connects traveler slot and spindle. The traveler is inserted in the slot which allows axial motion to traveler. The axial motion helps the traveler to move the yarn on the spindle back and forth.



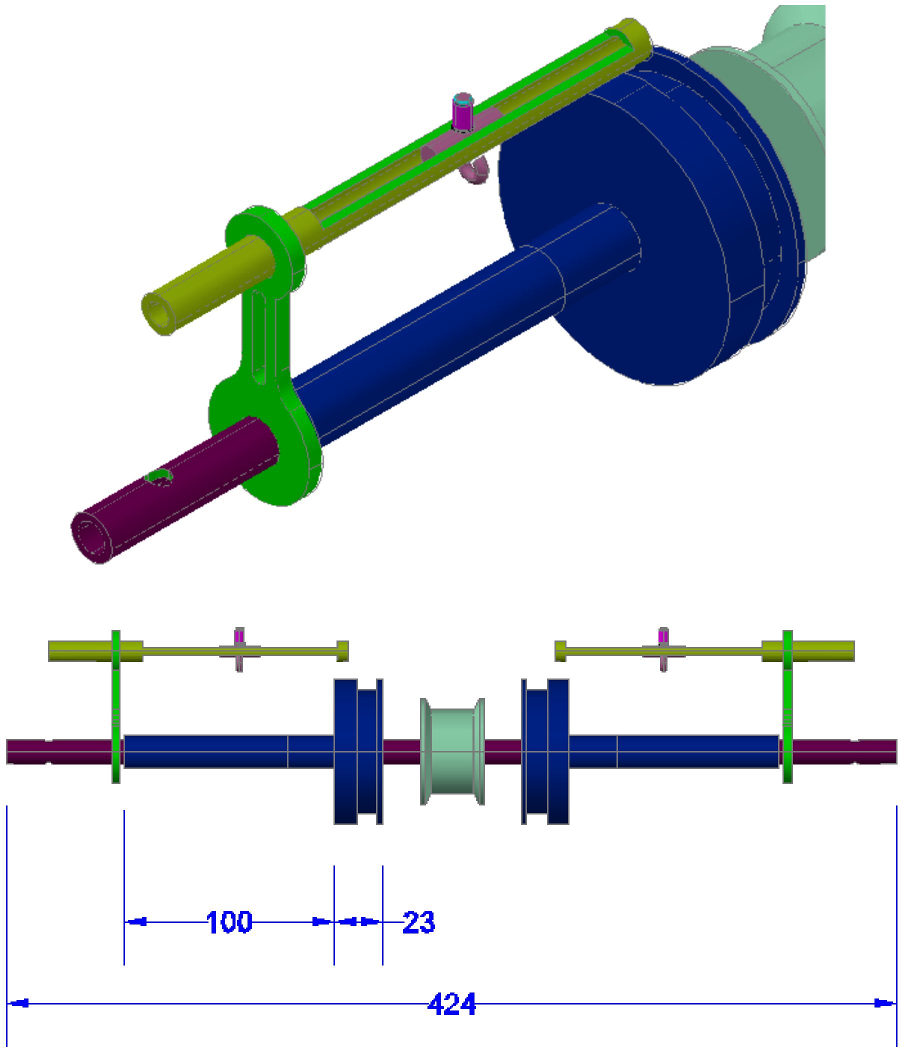


Figure 5.5 Subassemblies of the spinning parts

5.2.3 Yarn Building Controller

5.2.3.1 Traveler Guide and Traveler Guide Roller:- The ring guide provides a circular hole for each traveler which does not affects the rotational motion of the travelers and guide the ring to move axially back and forth.

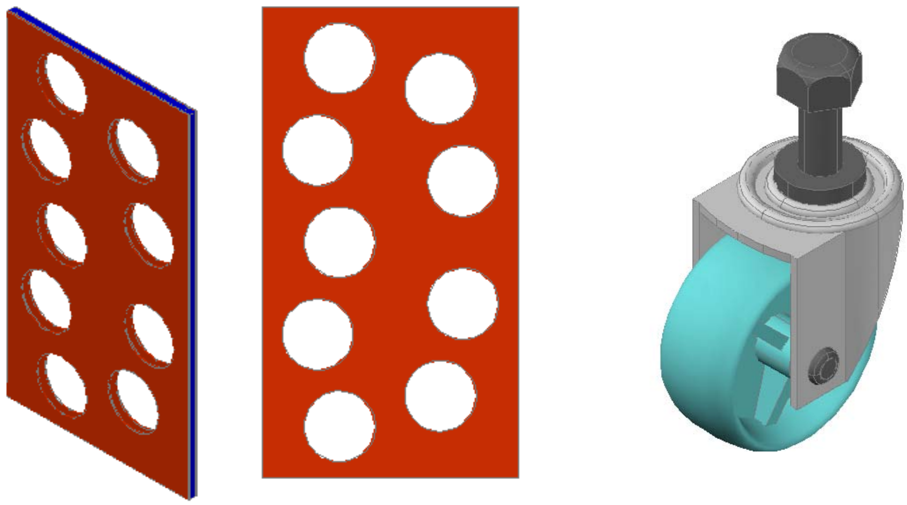


Figure 5.6 Traveler Guide and Traveler Guide Roller

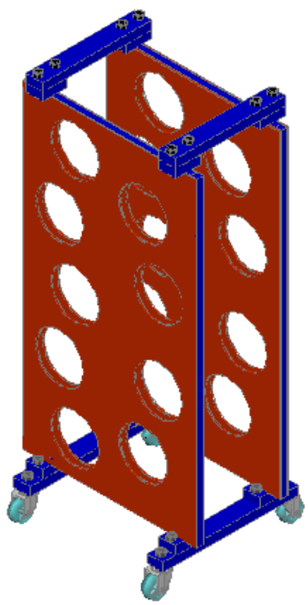


Figure 5.7 Sub Assembly of Controller

5.2.4 Input Holder and Drafting Parts

The input holder is used to hold the processed fibrous material which is ready for spinning. The fiber is feed to the front drafting rollers and then back drafting rollers. The speed of back drafting rollers is lower and the drafting rate is smaller. The front drafting rollers speed is much higher so it allows higher drafting rate making the fiber thinner.

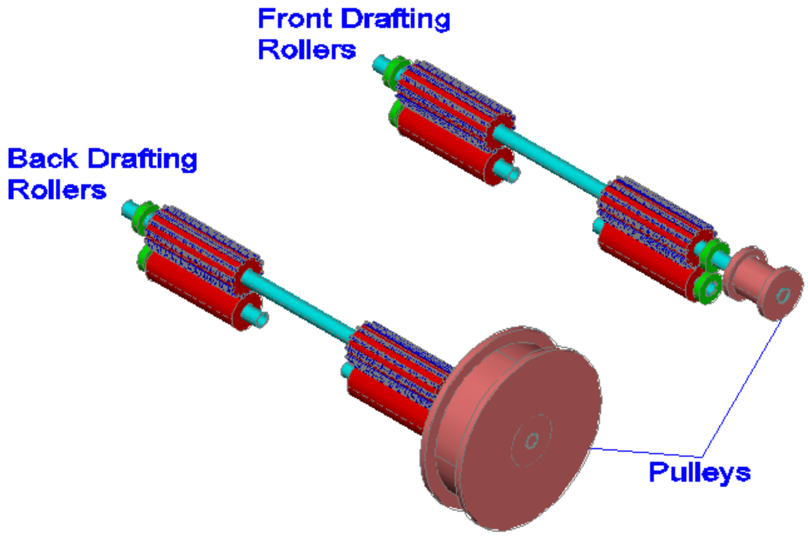


Figure 5.8 Drafting Parts

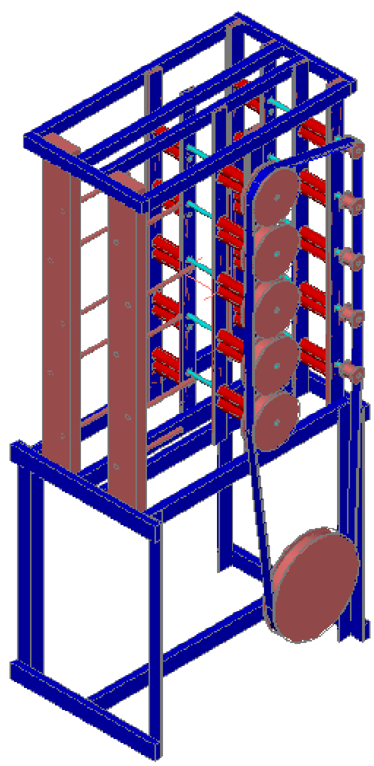


Figure 5.9 Subassembly of input holder and drafting parts

5.2.5 Driving Power and Its Transmission

One electric motor is the desired driving mechanism of the whole system. The power from the motor is transmitted to the main shaft through belt and pulley. As shown on the figure all the other pulleys worn gear and bevel gear mechanisms will be driven by the main shaft.

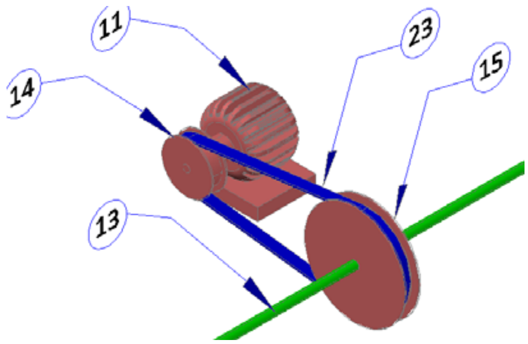


Figure 5.10 Motor and main shaft assembly

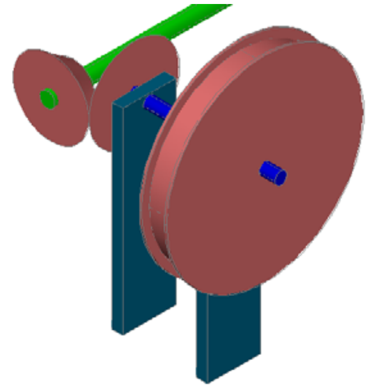


Figure 5.13 Bevel gear transmitting power from the main shaft to pulley

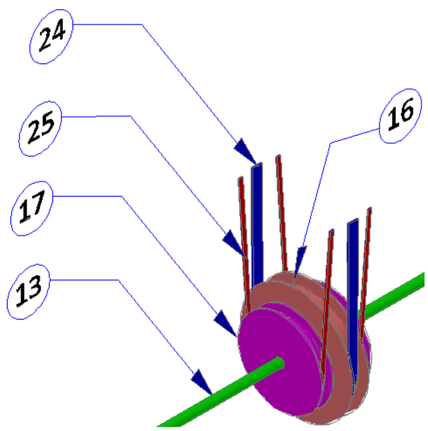


Figure 5.11 Spindle shaft and bobbin driver pulleys on the main shaft

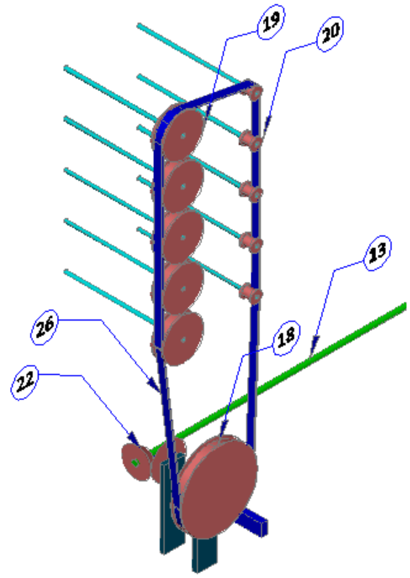


Figure 5.14 Power transmitting system to drafting shafts

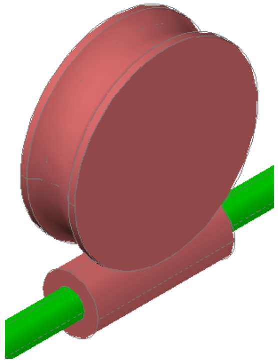


Figure 5.12 Worm gear on the main shaft to drive the controller

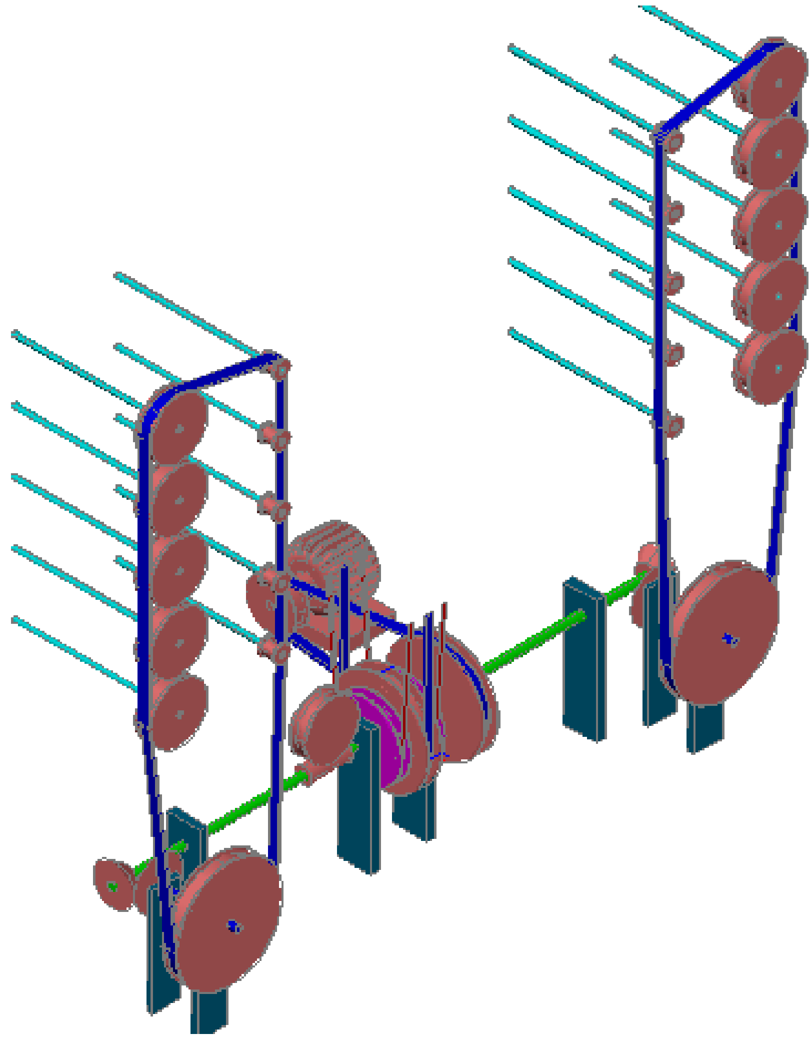


Figure 5.15 Overall power transmitting system of the spinning machine

The operation of the machine can be summarized as follows

1. The motor drives the main shaft using belt 1 which passes through pulley 1 and pulley 2
2. Pulley 3 drive spindle shafts
3. Pulley 4 drive spools/bobbins
4. Worm gear mechanism drives the traveler guide through controller arm. Also it changes plane of rotation from y-z plane to x-z plane.
5. Bevel gear transmits power to pulley 6 and pulley 7 by changing plane of rotation from y-z plane to x-z plane.
6. Pulley 5 drives the back and front drafting system.

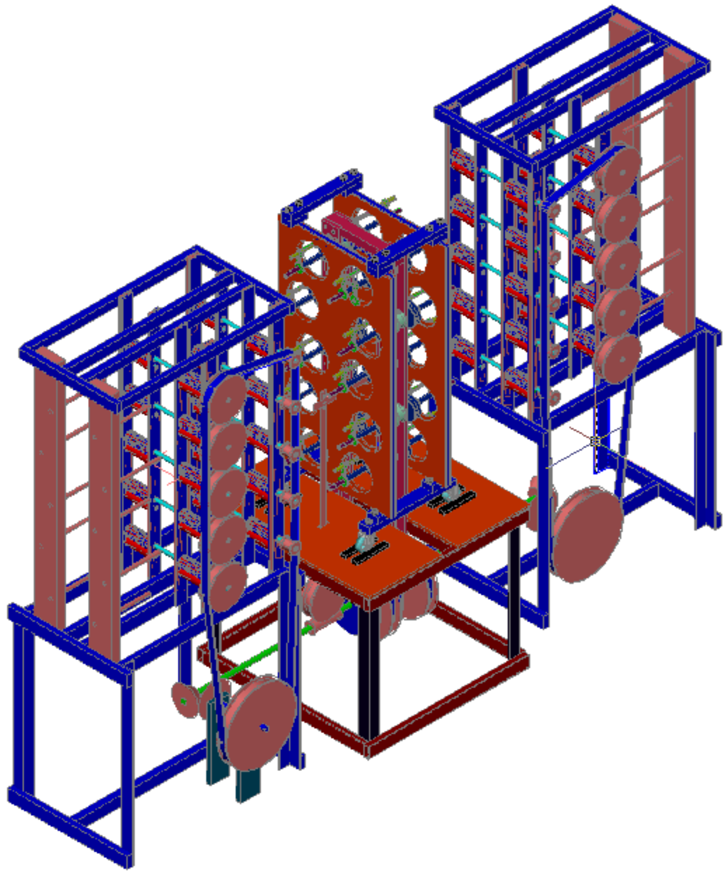


Figure 5.16 Assembly of the spinning machine

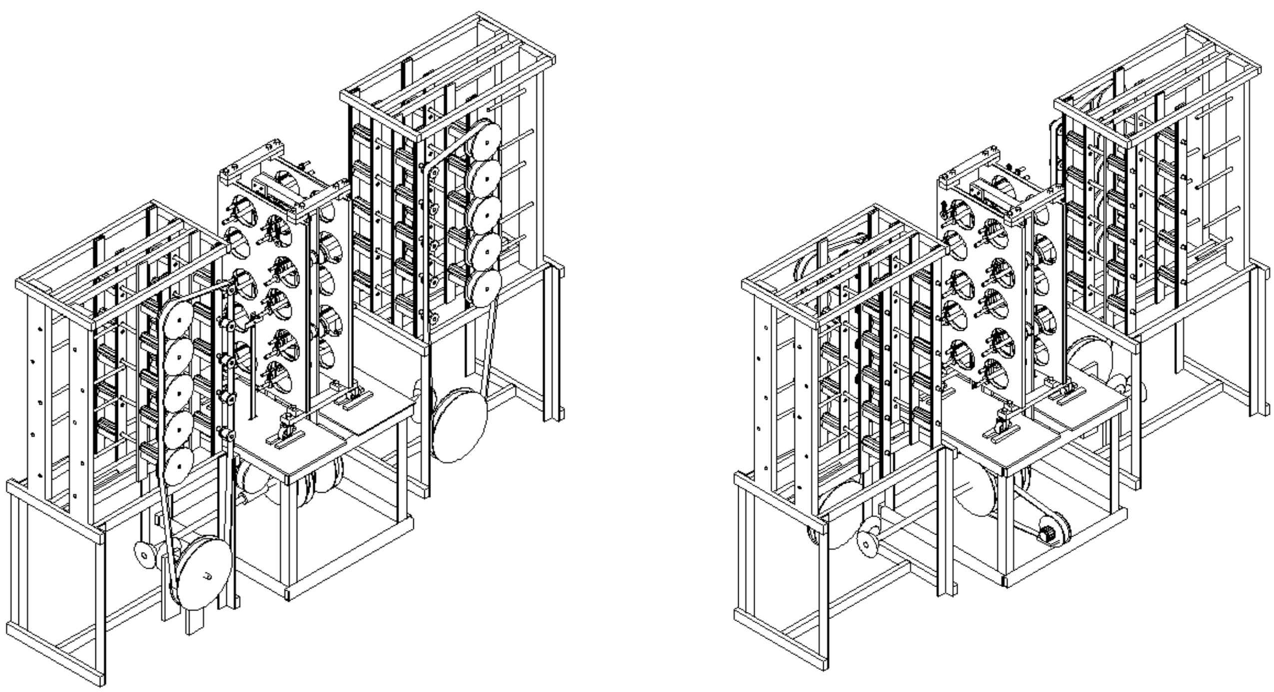


Figure 5.17 South west and north east assembly views of the spinning machine

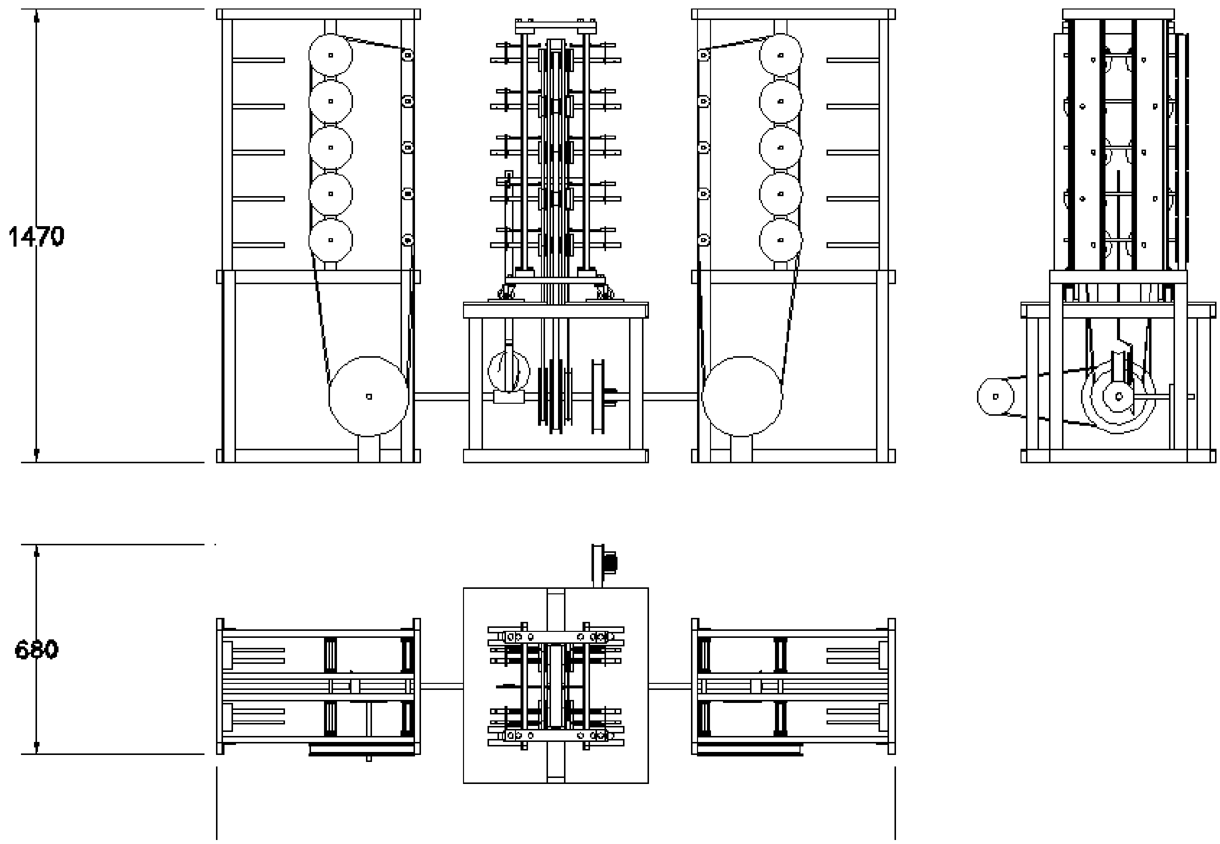


Figure 5.18 Assembley Multiview drawing

CHAPTER SIX

TWIST INSERTION AND GEOMETRIC ANALYSIS

6.1 Geometric Relationship of the Designed Spinning Machine

The geometry of the machine components are dependent on the amount of twist to be inserted on the yarn. Since the main objective of this thesis is to design a spinning machine that can produce yarn similar to hand spun yarn, the required amount of twist to be inserted is low. On this machine we have two drafting units with diameter 120mm and 30mm for the back and front drafting units respectively. This gives drafting ratio of 4. This drafting system reduces the roving or slubbing counts to an appropriate value so that, on twisting the drafting mass of the required yarn count is obtained.

As described in sec. 2.4.2 the speed of the bobbin in modern textile industries can be up to 25,000rpm and spinning wheels can spin with around 1000rpm. Considering simplicity of the machine, geometrical constraints and the objective to increase productivity of traditional spinning systems including spinning wheel we can set the speed of the bobbin above 1000rpm and below 25,000rpm.

Let's consider to use a motor with 2,000 rpm to drive the main shaft using flat belt as shown on the figure below.

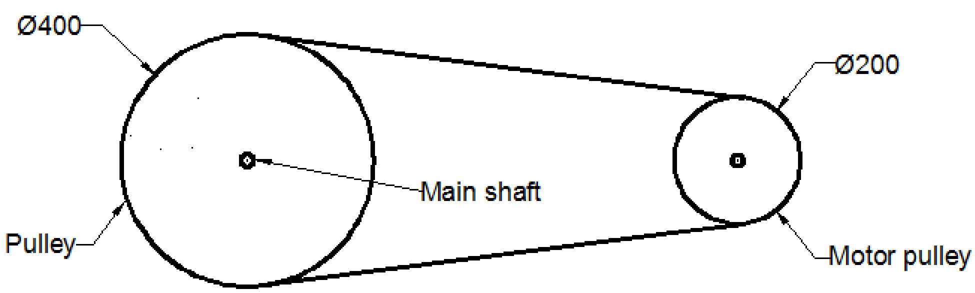


Figure 6.1 Main shaft and motor assembly

Based on the design => Motor speed = N_{mot} = 2000rpm

Motor pulley 1 = D_{mot} = 100mm

Main shaft pulley 2 diameter = $D_{m.shaft}$ = 200mm

Main shaft speed = $N_{m.shaft}$ = ?

$$N_{m.shaft} = D_{mot}/ D_{m.shaft} \times N_{mot}$$

Main shaft speed = $N_{m.shaft}$ = 100/200 x 2000 = 1000rpm

The diameter of the pulley on the main shaft which transfers motion to the spindle/bobbin shaft is 200mm. The diameter of spindle pulley is 40mm

Therefore : Main shaft speed = $N_{m.shaft}$ = 1000rpm

Main shaft pulley 2 diameter = $D_{m.shaft}$ = 200mm

Spindle pulley = $D_{s.s.p}$ = 40mm

Spindle speed = $N_{S.S}$ = ?

Ns.s = $D_{m.shaftt/}$ $D_{s.s.p}$ x $N_{m.shaft}$

Spindle speed = Ns.s = 200/40 x 1000 = 5000rpm

So, the spindle shaft will run at 5000rpm.

There are also two pulleys assembled on the main shaft which transfers motion to the spools on which spun yarn will be winded. The diameter of the pulleys of the spools is 60mm and the diameter of the two pulleys which transmits motion from main shaft to the spools is 150mm.

Therefore Main shaft speed = $N_{m.shaft}$ = 1000rpm

Main shaft pulley 3 diameter = $D_{m.s.p}$ = 150mm

Spool diameter = D_{spool} = 60mm

Spool speed = N_{spool} = ?

N_{spool} = $D_{m.s.p}$/D_{spool} x $N_{m.shaft}$

Spool speed = N_{spool} = 150/60 x 1000 = 2,500rpm

Now let's consider the motion transmission to the drafting units. As we can see from the design at the ends of the main shaft there are bevel gear mechanisms to transmit motion from the main shaft to the pulley 5 that transmits motion to the pulleys of the drafting units. To reduce the count of the yarn from the front drafting unit to the spool the speed of the front drafting unit should be much lower than the speed of the spindle. Therefore, the selection of the bevel gear ratio is dependent on the speed of the front drafting unit. Let's take the speed of the front drafting unit speed to be around 1000rpm.

Front drafting unit speed = $N_{F.D}$ = 1000rpm

Front drafting unit diameter = $D_{F.D}$ = 30mm

Back drafting unit diameter = $D_{B.D}$ = 120

Back drafting unit speed = $N_{B.D}$ = ?

Therefore; $N_{B.D} = D_{F.D}/D_{B.D} \times N_{F.D}$..6.1

Back drafting unit speed = $N_{B.D}$ = 30/120 x 1000 = 250rpm

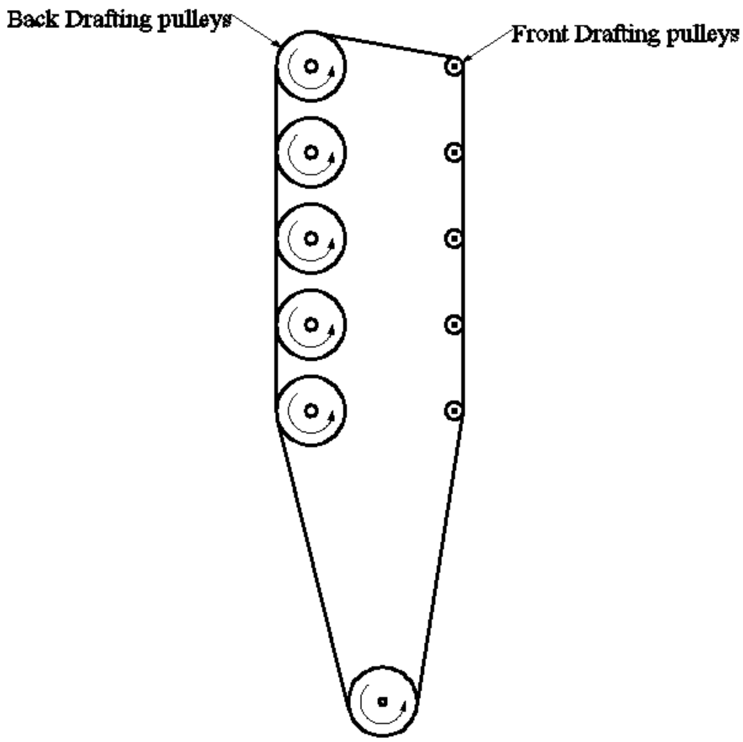


Figure 6.2 Drafting unit pulley system

The speed of the main shaft is 1000rpm. Let the pulley diameter that transmits motion from the bevel gear is 120mm, therefore the main shaft speed should be reduced to 250rpm. So, to get these speeds the bevel gear with ratio 4 = 1000/250 will be selected.

Based on these above values we can consider the following situations.

6.2 Twist Insertion and Yarn Production

The mechanism of twist insertion to the strand during ring spinning has been studied. The twisting of the strand occurs not only due to the rotation of twisting elements, but also due to the winding of yarn on the package. When the yarn is wound on a stationary cop by gripping and winding the yarn by hand, for every coil of yarn wind one turn of twist to the yarn is inserted. But the same yarn is over-end withdrawn from the cop, and all twists inserted during winding are removed during unwinding. Over-end unwinding rotates the yarn in the opposite direction. Since the yarn from the cop is over-end withdrawn during winding, the spindle speed is taken for calculating the twist in the yarn, whereas the flyer speed is taken for calculating twist in the roving due to the parallel unwinding of roving during spinning.

Twisting is a very essential process in the production of staple yarn, twine, cord and ropes. Twist is inserted to the staple yarn to hold the constituent fibres together, thus giving enough strength to the yarn, and also producing a continuous length of yarn. The twist in the yarn has a two-fold effect; firstly the twist increases cohesion between the fibres by increasing the lateral pressure in the yarn, thus giving enough strength to the yarn. Secondly, twist increases the helical angle of fibres and prevents the ability to keep the maximum fibre strength to the yarn. Due to the above effects, as the twist increases, the yarn strength increases up to a certain level, beyond which the increase in twist actually decreases the strength of staple yarn. The continuous filament yarn also requires a small amount of twist in order to avoid the fraying of filaments and to increase abrasion resistance. However, twisting the continuous filament yarn reduces the strength of the yarn. Yarn is often ply-twisted in a direction opposite to a single yarn twist to improve evenness, strength, elongation, bulkiness, luster and abrasion resistance, and to reduce twist liveliness, hairiness and variation in strength.

The twisting of fibres strands are carried out on a roving frame, ring frame, rotor spinning and DREF spinning machines etc. This twisted strand has to be wound on the delivery package in a certain form for easy withdrawal of these strands in the next process. Since the open end of the yarn is rotated in the rotor and DREF spinning systems, the delivery package has to be rotated axially to wind the yarn. The twisting and winding operations are separated in the open-end spinning. However, this is not possible on a roving frame or a ring frame.

There should be two rotating elements (the spindle and traveller or flyer and bobbin) in order to twist and wind the strand on the package. The winding rate should be equal to the delivery rate from the drafting device. As the winding on the diameter of the package varies continuously throughout the process, the difference in speed between the two elements also has to be varied continuously. Since the delivery rate is constant, the product of winding on diameter and the speed difference between the two rotating elements should be kept constant. On a roving frame, this is achieved by adjusting the bobbin speed continuously and keeping the flyer speed constant, whereas in ring spinning, only the spindle is rotated at a constant rate and the traveller is dragged around the ring by the yarn. Due to the frictional force between the ring and traveller, the required speed difference between the spindle and traveler is automatically adjusted. In both the ring and roving frame of the short-staple spinning system, the bobbin lead is used. For calculating twist in the roving, the flyer speed is taken into account, whereas in ring spinning, the spindle speed is considered.

Twist/cm in the roving = flyer speed in rpm/ delivery rate in cm/min............................6.2

Twist/cm in the yarn = spindle speed in rpm/ delivery rate in cm/min...........................6.3

The reasons for the above and the mechanism of twisting strands on a roving frame and ring frame are explained below.

6.2.1 Mechanism of twist insertion to the strand and Yarn Production

The diameter of the spool is 16mm but the diameter of the spool will increase as the yarn winded on it so, to calculate yarn production rate in length we have to calculate the average diameter. To do not affect the property of the yarn produced the diameter of the yarn winded on the spool should not be more than 50mm.

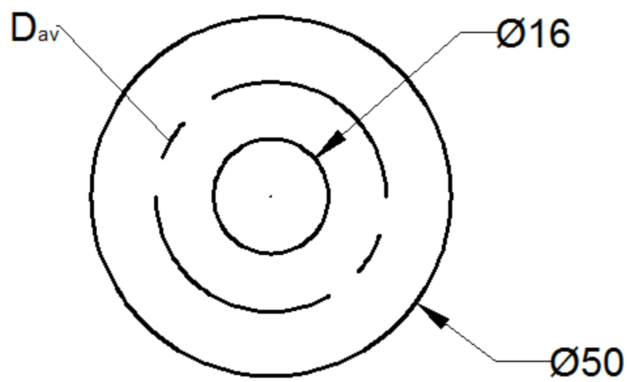


Figure 6.3 Yarn geometry on the spool

$L_{min} = \pi d_{min} = \pi \times 16 = 50.2mm$

$L_{max} = \pi d_{max} = \pi \times 16 = 157mm$

$L_{av} = (157 + 50.2)/2 = 103.6mm$

Therefore, $D_{av} = L_{av}/\pi = 103.6/\pi = 33mm$

Using this average value diameter we can consider the following situations for the deigned spinning machine.

I. Twist insertion to the yarn when the spindle is stationary

We assume that the spindle is stationary and the traveler rotates in the ring frame. Each revolution of the traveler winds one coil of yarn onto the cop. This is similar to gripping and winding the yarn on a cop by hand. The yarn will rotate 360^0 per coil wind while winding the yarn onto a stationary cop by hand; hence the winding causes yarn twisting.

Length of yarn wound per revolution of traveler = πd..6.4

Turns/cm due to winding = $1/\pi d$..6.5

Where d – Winding on diameter of cop or bobbin in cm.

If the yarn is unwound in parallel from the cop, the yarn will retain all the twists present in the yarn, whereas if the yarn is over-ending unwound, unwinding a coil removes one turn of twist. The unwinding causes twisting. So, the twists inserted into the yarn during winding are removed during over-end unwinding. The over-end withdrawal may be from any side of the cop. If the traveller rotates in a clockwise direction to wind the yarn onto the cop, each coil of wind inserts one turn of 'Z' twist to the yarn. When the same is over-end unwound, every unwinding coil inserts one turn of twist in an 'S' direction, and so the resultant yarn will not have any twist.

II. Twist insertion into the yarn when the traveler is stationary

We assume that the traveler is fixed on a stationary ring and that the spindle is rotating at a constant speed. Every revolution of spindle winds one coil of yarn onto the cop. Here winding does not cause twisting, and hence the yarn in the cop will not have any twist. But if the yarn is over-end unwound, every unwinding of a coil of yarn inserts one turn of twist into the yarn.

Turns/cm due to over-end unwinding = $1/\pi d$..6.6

The direction of twist insertion during over end unwinding depends on direction of yarn winding. If the spindle rotates in an anticlockwise direction to wind the yarn onto the cop, during over-end unwinding a 'Z' twist will be inserted into the yarn. But if the same yarn is unwound in parallel, the yarn will not receive any twist.

III. Twist insertion onto the yarn when both spindle and traveler rotate in opposite direction

It may be wondered why it should be necessary to rotate the traveler and spindle in the opposite direction, and also how to rotate the traveler in the opposite direction. This is only to enable the reader to clearly understand the mechanism of twisting. When both the spindle and traveler rotate in the opposite direction, each revolution of the spindle and traveler winds one coil each. The length of yarn wound per min and twist/cm can be calculated.

Length of yarn wound per min = π d (NS+NT) 6.7

Twist/cm due to winding = - NT/ π d (NS+NT) 6.8

Where NS – spindle speed in rpm,

NT – traveler speed in rpm

If the spindle and traveler rotate in clockwise and anticlockwise directions respectively, the direction of twist insertion due to winding would be 'S'. But during over-end unwinding, the direction of twist insertion would be 'Z' + and - signs are used to represent the Z and S twist directions respectively.

Twist/cm due to over-end unwinding = (NT/ π d (NS+NT)) + (NS/ π d (NS+NT)) 6.9

Twist/cm in the yarn after over-end withdrawal = (NS/ π d (NS+NT) 6.10

IV. Twist insertion onto the yarn when the spindle leads the traveler

In ring spinning, both the spindle and traveler rotate in the same direction. However, the spindle rotates at a higher speed than the traveler. If both rotate at the same speed, only the twisting of yarn takes place without winding. Due to the difference in their rotational speeds, the winding of the yarn takes place on the cop.

Length of yarn wound on the cop per min = πd (NS –NT) 6.11

Due to rotation, both spindle and traveler insert twists onto the yarn. If both the spindle and traveler rotate in a clockwise direction, a ‘Z’ twist is inserted to the yarn.

Turns/cm in the yarn = NT/πd (NS –NT) 6.12

The winding rate should be equal to the delivery rate.

Length of yarn delivered (cm/min) = πd (NS –NT) 6.13

Here winding takes place in similar conditions to when the traveler is stationary and the spindle is rotating; hence winding does not insert any twist onto the yarn. On the other hand, during over-end unwinding one turn of twist is inserted for every unwound of coil.

Turns/cm for unwinding = 1/πd

Total twist present in the yarn after over-end unwound = NT/πd(NS –NT) + 1/πd

= NS/πd(NS-NT) 6.14

Since yarn from the ring cop is normally over-end withdrawn during the winding process, the spindle speed is taken for calculating the turns/cm in the yarn instead of using traveler speed. However, turns/cm in the roving is calculated by taking the flyer speed into account. This is due to the parallel withdrawal of roving during spinning.

V. Twist insertion onto the strand when flyer leads bobbin

Due to the difference in the speeds of the flyer and the bobbin, the winding of roving takes place on the bobbin.

Twist/cm due to twisting = NB / πd(NF-NB) 6.15

Twist/cm due to winding = (NF-NB)/ πd(NF-NB) 6.16

Twist/cm in the roving = NF / πd(NF-NB) 6.17

Where NF - flyer speed in rpm,

NB - bobbin speed in rpm.

If the roving is unwound in parallel, the roving will have the same amount of twist as in the bobbin, but if it is over-end withdrawn, it will lose a certain amount of twist during unwinding.

Turns/cm due to over-end withdrawal = - (NF-NB)/ πd(NF-NB) 6.18

Turns/cm in the roving after over-end withdrawal = NB/πd (NF-NB) 6.19

6.2.2 Summary and conclusion

1. Yarn will rotate 3600 per coil wound while winding yarn onto a stationary cop by hand. When it is over-end unwound from the cop, all twists present in the yarn are removed. Hence both winding and over-end unwinding cause twisting, but in opposite directions.

2. If the yarn is wound onto the cop by feeding the yarn perpendicular to the cop and rotating it, winding the yarn will not cause any twisting. But if the yarn is over-end withdrawn, the yarn will receive one turn of twist per coil unwound.

3. If the flyer leads the bobbin in the roving frame, twisting of the roving takes place due to both twisting and winding.

4. Since the yarn from the cop is over-end withdrawn during winding, the spindle speed is taken for calculating the twist in the yarn, whereas the flyer speed is taken for calculating the twist in the roving, due to parallel unwinding of the roving during spinning.

5. The over-end unwinding of yarn helps in getting extra twist to the yarn, and the parallel unwinding of roving will not introduce any extra twist to the roving. If the roving is over-end withdrawn during spinning, every coil unwound will insert one turn of twist onto the roving. Hence the break draft and the setting of the back roller have to be increased to facilitate the breakage of the twist present in the roving. Otherwise, undrafting of the strand will occur during drafting. Hence the roving is normally unwound in parallel from the bobbin during ring spinning.

CHAPTER SEVEN

RESULTS AND DISCATIONS

7.1 Output

The raw output of one machine is spinning of yarn on 20 bobbins simultaneously with an average time of ten minutes excluding the time required to insert and remove bobbins. As a result, it is believed that implementation of improved spinning machine will improve the method of work, increase the traditional yarn production rate and provides an opportunity for micro and small scale enterprise operators to utilize work force efficiently by producing a number of cop yarns in a short time. It will also help to create awareness for them to focus their technological potential to identify the drawback and to propose improvement needed on simple machines they owe.

7.2 Benefits and Beneficiaries

It is known that spinning work to prepare shema cloths is done by women, since culturally it is womens' job in most parts of Ethiopia. Most of them are spinning cotton by their hands and thigh. In this way, if one woman stays spinning for one day she may spine maximum of ten cop yarns which is very time taking, tiresome and boring. But if newly designed machine is developed and implemented, she can spine 100's of cop yarns per day. Imagine the difference! At this point, we have to remind that wives and children of weavers are suffering a lot than others; they are winding and spinning always with their hands and lags/thigh to fulfill the demand of their husbands weaving capacity. This operation is one of the means of creating child and women labor abuse. So, the first beneficiaries are *women and children.*

When this machine is implemented and applied, two direct operating labors will be employed per machine with a good salary. But weavers are working all over Ethiopia; therefore it will create high employment opportunity throughout the county.

Generally the benefits of this spinning machine is saving time and man power for the operators or weavers at the same time increasing the production rate of traditional cloths and then increasing their income. As the production rate of traditional cloths increases, the weavers will start exporting their product to other countries with more quantity and quality than the current export generating income to the country. So, the beneficiaries of this machine are all the inventor, owners who will buy the machine, the weavers and the government/people of the country. On the other way, if this machine is produced and disseminated not only in Ethiopia but it will be exported to other African countries, this will lead us to produce and export the machine to other countries which will generate income to the manufacturer and the country.

This machine will improve the quality of the society by changing the working system from hand and leg to mechanized machine; utilizing the farmers agricultural product cotton as raw material increasing quality and quantity of our cultural clothes and other textile products of weavers; changing the attitude of community towards weaving and weavers to give respect and improving the image of weaving and weavers (Weavers were looked down specially upon in Northern Ethiopia).

CHAPTER EIGHT

CONCLUSION AND RECCOMENDATION

This thesis is about introducing new innovative cotton spinning machine. In this thesis one of our indigenous knowledge is insuring the existance of our cultural products which expresses our diginity and prid by increasing productivity of clothes.The design of the machine machine includes main components of spinning system like power transmmision, spining mechanism, drafting system e.t.c.

Finally, based on the designeded spinning machine it will be possible to spin on a number of spindles at the same time with high improvement when compared with the currently used winding and spinning wheel. The proccess of making textile from cotton is not only spinning and winding but also pre spining operations like cleaning cotton and sepatating seed from cotton (ginning) and preparing cotton for spining (fiber) and post winding operations weaving, knitting, printing and garment. Therefore, it is obvious that researchers and other stakeholders should be able to improve specially these remaing operations to achieve the development of the tixtile sector owned by micro and small scale industy.

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