

**Design Of A Software To Analyze Mass Variation Of Ring
Spun Yarn**

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**Supervisor
Prof. Dr. Ali KÝREÇCÝ**

**by
Mehmet Erdem ÝNCE
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Approval of the Graduate School of Natural and Applied Sciences

Prof. Dr. Saadettin ÖZYAZICI
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Assist. Prof. Dr. Mehmet TOPALBEKÝROĐLU
Chairman of the Department

This is the certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Prof. Dr. Ali KÝREÇCÝ
Supervisor

Examining Committee Members

Prof. Dr. Ali KÝREÇCÝ

Assoc. Prof. Dr. Osman BABAARSLAN

Assist. Prof. Dr. Mehmet TOPALBEKÝROĐLU

ABSTRACT

DESIGN OF A SOFTWARE TO ANALYZE MASS VARIATION OF RING SPUN YARN

İNCE Mehmet Erdem

Master thesis, Textile Engineering Department

Supervisor: Prof. Dr. Ali KÖREÇCİ

May 2005

Since food, clothing, and shelter are the most fundamental of our requirements, the textile industry is a subject of very general importance and interest. Quality has become one of the most important criteria when selecting a product, not only in textiles but also in other types of product. The reasons for quality control are to ensure adequate quality of product and minimum trouble in processing. Testing for quality control falls into two categories: laboratory (or off-line) testing and on-line monitoring. In off-line control, samples of the product are taken to the laboratory for testing. Various sorts of test apparatus are used. In on-line control, sensors are fitted into the machine which generates signals that describe some function of the material; these signals are processed by a computer. On-line control has more advantages than off-line control because the product can be interfered during the production process if necessary.

In this study, a software was designed to analyze yarn evenness. An optic sensor was placed on Premier Tester 7000 evenness test device and data about yarn diameter variation obtained. These data converted into numerical quality parameters of yarn such as U_m %, CV_m %, thin places, thick places, and neps number. In addition, graphical quality parameters such as diagram, spectrogram, and histogram were drawn by using the designed software.

Key words: Quality, quality control, yarn faults, software, Delphi, yarn evenness, on-line control, photoelectric sensor.

ÖZ

RÝNG ÝPLÝĐÝ KÜTLE VARYASYONUNU ANALÝZ EDEN BÝR BÝLGÝSAYAR PROGRAMININ TASARLANMASI

ÝNCE Mehmet Erdem

Yüksek Lisans Tezi, Tekstil Mühendisliđi Bölümü

Tez Yöneticisi : Prof. Dr. Ali KÝREÇCÝ

Mayýs 2005

Yemek, giyinmek ve barýnmak, insanođlunun en temel gereklerinden olduđundan, tekstil endüstrisi herkesin ilgisini çeken, önemli bir konudur. Kalite sadece tekstil ürünlerinin deđil, diđer bütün ürünlerin seçiminde de en önemli kriterlerden biri olmu°tur. Kalite kontrolün amacı istenen kalitede ürünü minimum üretim problemi ile üretmektir. Kalite kontrol laboratuvar þartlarında uygulanan (off-line) kontroller ve üretim aþamasýnda uygulanan (on-line) kontroller olmak üzere ikiye ayrýlmaktadır. Off-line kontrolde ürün örnekleri laboratuvar ortamýnda çeþitli cihazlar kullanýlarak ölçülmektedir. On-line kontrolde ise makine üzerine yerle°tirilen sensörler üretilen materyalin karakteristiđi hakkında sinyaller üretmekte ve bu sinyaller bilgisayar tarafından iþlenmektedir. On-line kontroller ürün oluşumu esnasýnda müdahaleye olanak verdikleri için daha avantajlýdırlar.

Bu çalıþmada iplik düzgünlüđünü analiz etmek amacıyla bir bilgisayar programý tasarlanmýþtır. Optik bir sensör Premier Tester 7000 düzgünlük cihazý üzerine yerleþtirilmiþ ve iplik çapý dataları elde edilmi°tir. Tasarlanan programda bu datalar numerik iplik kalite parametrelerine (%Um, %CVm,, ince yer, kalýn yer, neps) dönüþtürülmüþtür. Ayrýca diagram, spektrogram ve histogram gibi grafiksel iplik kalite parametreleri de çizilmi°tir.

Anahtar kelimeler: Kalite, kalite kontrol, iplik hataları, bilgisayar programý, Delphi, iplik düzgünlüđü, on-line kontrol, fotoelektrik sensör.

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CHAPTER 1

INTRODUCTION

1.1. Introduction

Since food, clothing, and shelter are the most fundamental of requirements of human being, the textile industry is a subject of very general importance and interest. From earliest times, people have used textiles of various types for covering, warmth, personal adornment, and even to display personal wealth [1, 2].

People are more interested in what to wear today comparing the past, since it is part of their character or style in modern society. Wearing fashionable garments or garment of well-known brands in the light of quality is the general behavior of individuals in the past thirty years, especially in the last decade.

Quality has become one of the most important criteria when choosing a product, not only in the textiles but also in the other types of the products. Consumer behavior has always tended to buy the good quality with the reasonable price where product quality significance is growing increasingly in these days [3].

Yarn quality is one of the major quality parameters that affect the fabrics' and finally garments' quality. Since the yarn quality has a great effect on the finished product, the measurement of yarn quality is an important issue in textile industry. The most popular quality parameter of yarn is named as yarn evenness. Yarn evenness can be defined as the variation in weight per unit length of the yarn or as the variation in its thickness. There are number of different ways of assessing it [4].

Yarn evenness is the most important parameter of quality. It affects directly all property of yarn. Mechanical, drawing and raw material faults cause evenness. These faults that occur in the yarn affect the yarn strength, yarn appearance and totally yarn quality. Because of great importance of identifying yarn evenness for quality, yarn evenness tester is the most important tool in yarn quality control laboratory. Measurement for evenness of yarn is performed by random selection of bobbins from each machine every day in a yarn plant. If there is a fault in these bobbins, which are

taken randomly, some causes are sought for. Therefore, this quality control can not be reliable. For example; if there is a fault except the chosen bobbins or if it occurs some faults that caused raw material after chosen the bobbins, until next measurement yarn will be manufactured defectively. As a result, not only time but also material is lost.

In order to prevent these problems, yarn evenness must be controlled during the production. On-line evenness control can be applied each spindle separately in a short time. This work aims the design of a software to analyze mass variations of ring spun yarns, calculations of quality parameters and their graphical representation. This study, in fact, is a continuation of a previous Ms. study which is named as “On-line quality control of spun yarns.” For that study, an experimental set-up was prepared and on-line measurement performed, but calculation of quality parameters and their graphical representations were not done. Besides this, there were some differences between actual and measured values of mass variations of the yarns because of sensitivity of the sensors used. The study may be divided into following steps;

- a) Numerical calculations of quality parameters of these yarns such as: unevenness (U_m %), coefficient of variation (CV_m %) and spectrogram.
- b) Graphical representation of these parameters. This step requires the design of computer software that is the main part of the study.
- c) Modification on the readily available ring spinning machine to obtain more accurate data and on line measurements of mass variations for different yarns as sample tests.

1.2. Evenness Testing

The most important property of a yarn is the number of fibers in a cross-section and the variation of this number along the yarn is the most fundamental measure of irregularity. This concept should be borne in mind as the methods of measuring irregularity are considered.

The cheapest and quickest method, for yarn evenness test at least, is to make a visual examination by looking at it as a yard or so is drawn off the package by hand. At the

other extreme, highly complicated electronic apparatus may be used. Available yarn evenness test methods are [5];

- a) Visual methods
- b) Variation in thickness under compression
- c) Electronic capacitance testers
- d) Photoelectric testers

1.2.1. Visual examination

1.2.1.1. Taper board

Yarns can be examined by wrapping them on to a mat black surface such as a piece of flat board as shown in Figure 1.1. The wraps should be equally spaced to avoid optical illusions of irregularity and blackboards examined under good lighting conditions.

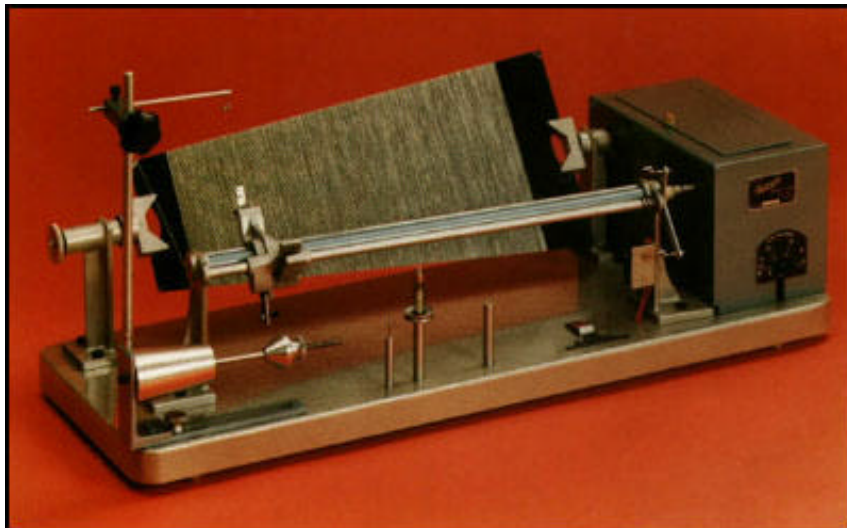


Figure 1.1. Taper board and yarn examiner [6]

A particular mill may set up its own standards of judgment, but in the U.S.A. the A.S.T.M. has a series of Cotton Yarn Appearance Standards which are photographs of different counts with the appearance classified in four grades.

Periodic variations in the yarn may cause patterns to appear on the blackboard. If such a fault is suspected, the yarn may be wrapped on a tapered board. The optical effect is almost like the grain in wood. At the point where the peak of the pattern occurs the board height is a multiple of the wavelength of the fault.

1.2.1.2. Shirley yarn diameter projector

Another visual examination of yarn evenness method is the Shirley Yarn Diameter Projector (Figure 1.2). In this instrument, briefly, a magnified silhouette of a short length of yarn is projected on to a ground glass. The solid shadow is measured and the outstanding fibers are ignored. Two hundred readings are taken at random along the yarn. From the results the mean yarn diameter and the standard deviation are calculated. Since personal judgment enters into the measurement (the decision where the solid shadow ends) it is recommended that the same person always carries out such test in the laboratory [7].

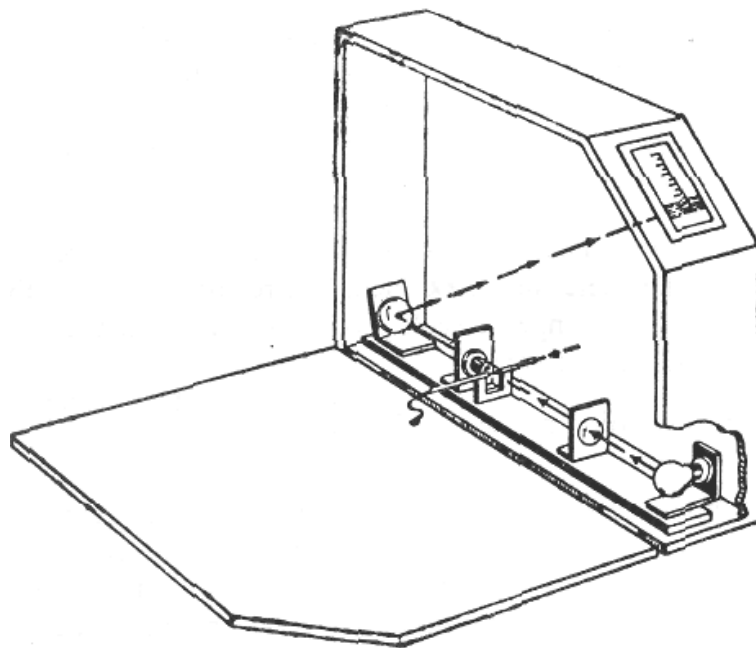


Figure 1.2. Shirley yarn diameter projector [7]

1.2.2. Yarn testing by compression methods

Slivers and rovings are soft enough to conform to the rectangular shape of the groove through which they run, but the twist in yarns causes them to be too hard for this purpose. A yarn tester as shown in Figure 1.3. overcomes this difficulty by using a very lightly loaded radiused shoe resting on the yarn, with the yarn running over a flat anvil. Only 2-5 g pressure is applied to the yarn. It has been found that with a light pressure the measurements of yarn thickness are closely correlated with the weight per unit length. The recording of the yarn thickness variation takes the form of an optical arrangement in which a beam of light is reflected from a small mirror on to a moving strip

of photographic paper. In this way the movement of the shoe may be magnified 200 to 500 times, and a permanent record of the variation obtained.

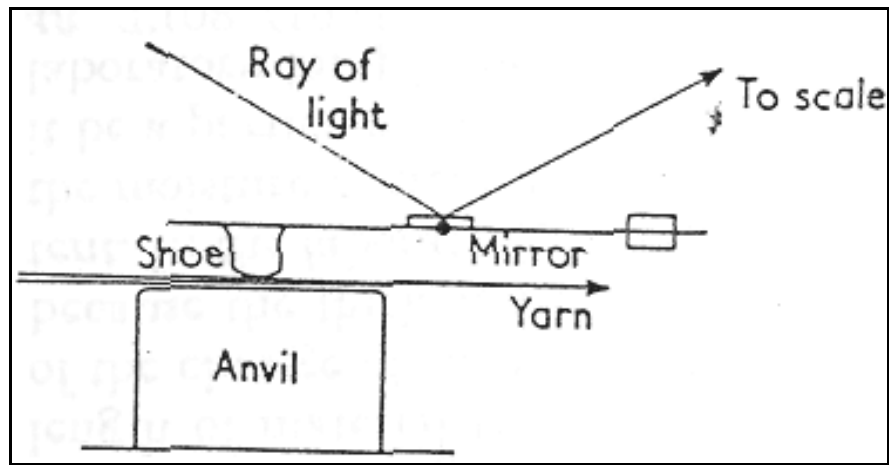


Figure 1.3. Yarn testing by compression (Anderson yarn tester) [5]

In LINRA yarn diameter tester, shown in Figure 1.4., the yarn passes round a series of rollers so that it lies between four nips, the pressure being about 5 g. The four thicknesses so measured are equally spaced within 1 in. The top roller supports a small anvil on which the plunger of the micrometer rests. Hence, a series of measurements may be taken along the yarn. Modifications to such an apparatus can convert it from a hand-operated instrument with intermittent measurement to a continuous tester with the movement of the top roller being used to actuate mechanical or electrical pen recorders.

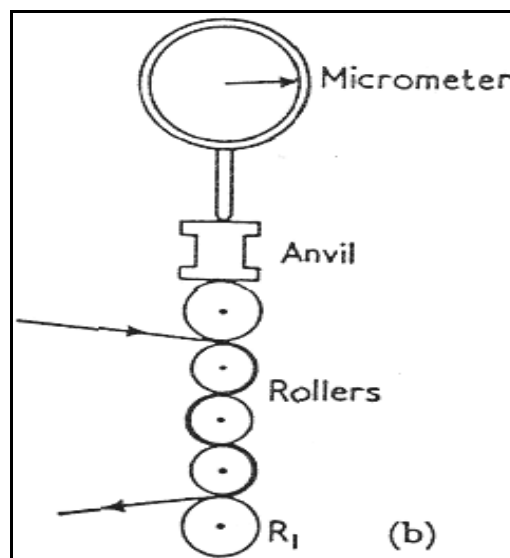


Figure 1.4. Yarn testing by compression (LINRA roller yarn diameter tester) [5]

1.2.3. Electronic capacitance testers

The measuring device of an electronic capacitance tester is a parallel-plate air capacitor. Under certain conditions, the effect of introducing a non-conducting material such as a sliver or yarn into the space between the plates is to change the capacity of the capacitor, the change being proportional to the weight of material present. If, therefore, the material is drawn through the capacitor continuously, the changes in the capacity will follow the variation in the weight per unit length of the strand, the unit length being the length of the capacitor. It is necessary to detect the changes in capacity and to translate them electronically into meter readings which indicate the coefficient of variation. At the same time a trace of the variation should be made on a pen recorder if required [5, 7].

1.2.3.1. The Fielden-Walker yarn evenness recorder

Most of the main features of electronic capacitance type tester can be seen in Figure 1.5;

- a) The measuring capacitor. Four sizes are available to accommodate a range of materials from slivers to fine yarns.
- b) The guides. These lead the material across the air gap in the correct position and, where necessary, give it right shape of cross-section.
- c) The creel to hold the material and allow smooth withdrawal from the package.
- d) The take-up rollers to pull the material through the capacitor.
- e) The yarn reel to collect tested yarn.
- f) Meter A, which indicates the deviation the momentary variation of the material.
- g) Meter B, which indicates the deviation from the mean level.
- h) Meter C, which indicates the mean level.
- i) The balance and sensitivity controls to adjust the instrument.
- j) The damping switch. When in operation, the pen of the recorder follows a smoother course.
- k) The pen recorder. The pen follows the movement of the pointer of meter A;

the chart speed can be varied by change wheels to give a range of chart construction.

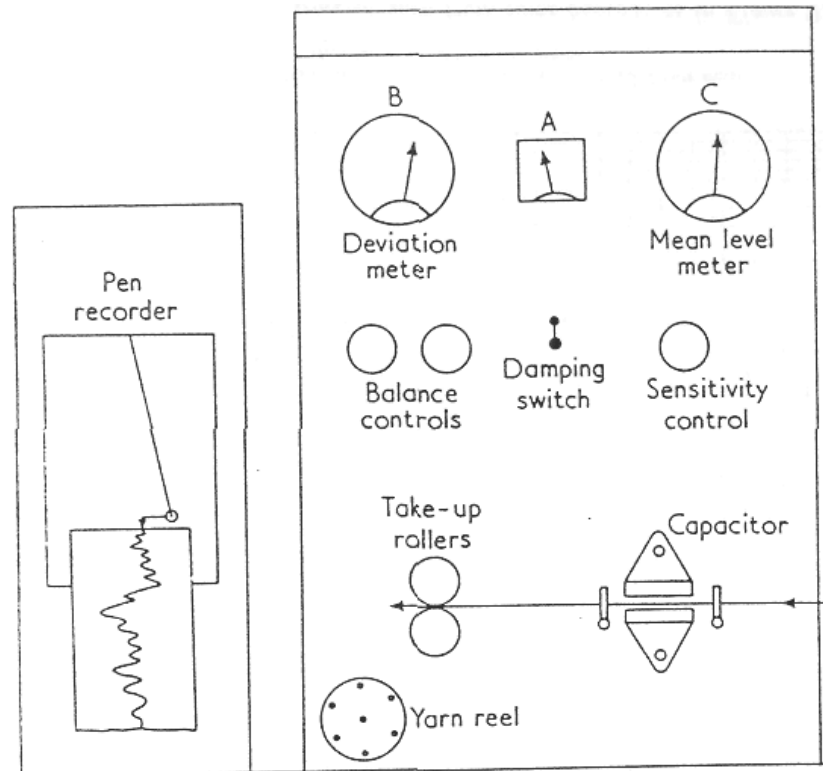


Figure 1.5. The Fielden-Walker evenness tester [5]

1.2.3.2. The Uster evenness tester

A schematic diagram of this evenness tester is shown in Figure 1.6. Two oscillators A and B have equal frequencies when there is no material in the measuring capacitor C. When the two frequencies are superimposed the difference in frequency is zero.

The presence of material in the capacitor causes its capacity to change and so alter the frequency of the oscillator A. There will then be a difference between the two frequencies which varies according to the amount of material between the capacitor plates. Suitable circuits D translate these frequency differences into signals which (1) are indicated on the meter M, (2) drive the pen of the recorder, and (3) are fed into the integrator which indicates the average irregularity either as percentage mean deviation or coefficient of variation according to the model used [5,7].

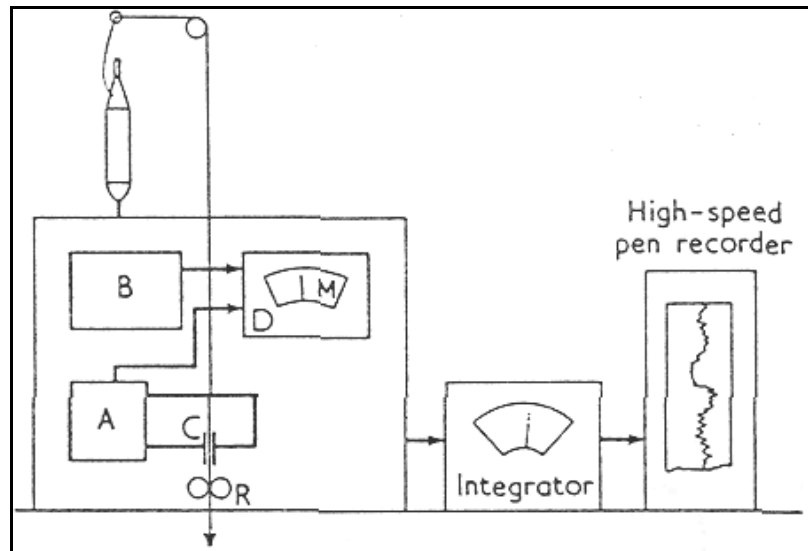


Figure 1.6. Schematic diagram of the Uster evenness tester [5]

1.2.4. Photoelectric testers

When a beam of light is directed on to a photoelectric cell an electric current is produced. The magnitude of the current is directly proportional to the intensity of the light falling on the light-sensitive part of the cell. If part of the light is cut off by a yarn passing between its source and the photoelectric cell, the current flowing will vary as the thickness of the yarn varies. Irregularity testers based on this principle is shown in Figure 1.7.

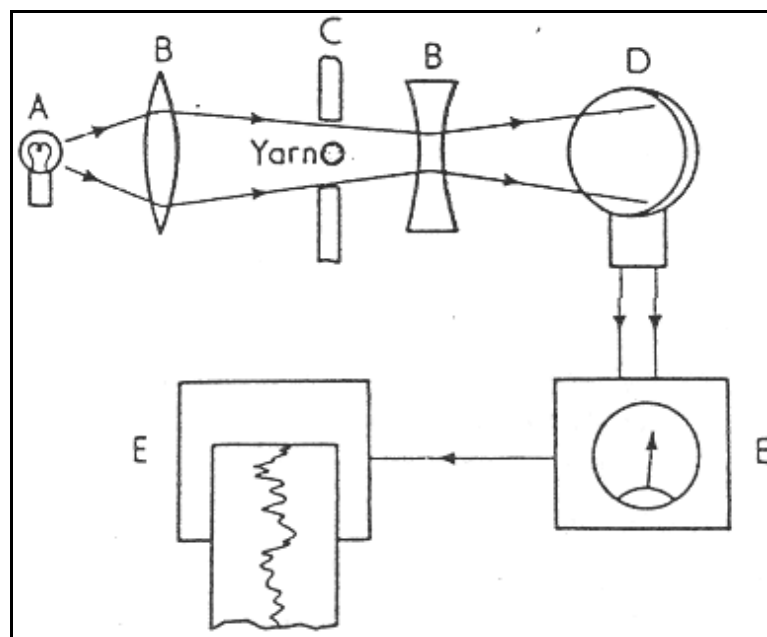


Figure 1.7. Schematic diagram of a photoelectric evenness tester [5]

- a) A stabilized source of light (A).
- b) An optical system to control the light (B).
- c) A slit of variable width through which the yarn passes (G).
- d) A photoelectric cell (D).
- e) Suitable meters and recording instruments to measure the current variations and produce an irregularity trace (E)
- f) A yarn-control device.

1.3. Literature Survey

In the light of the aim of the thesis, a literature research has been made and similar studies from researchers all around the world review for their conclusion.

Chatterjee, Bhattacharyya and Majumdar measured the mass variation of yarns spun on Dref-III spinning machine in capacitance type sensor using the parallel type of capacitor and transmitted the signal to the computer where the signal of mass variation in + and - range can be shown on the monitor in graphical manner through on-line using Q-Basic computer programming language. The graphical value can be stored and can also be displayed if required [9]. Block diagram of the measurement process of this study is shown in Figure 1.8.

On-line measurement of cotton diameter variation on the computer screen of this study is shown in Figure 1.9.

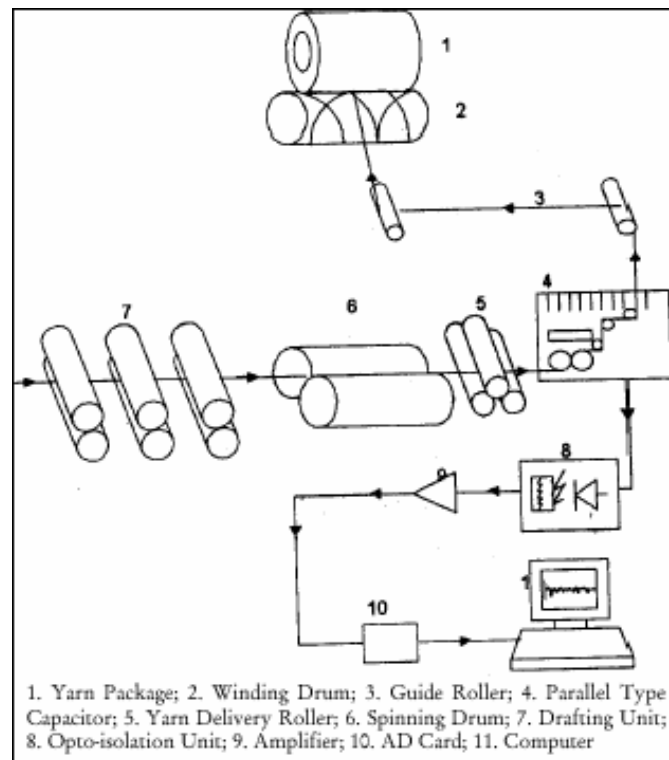


Figure 1.8. Block diagram of the measurement process [9]

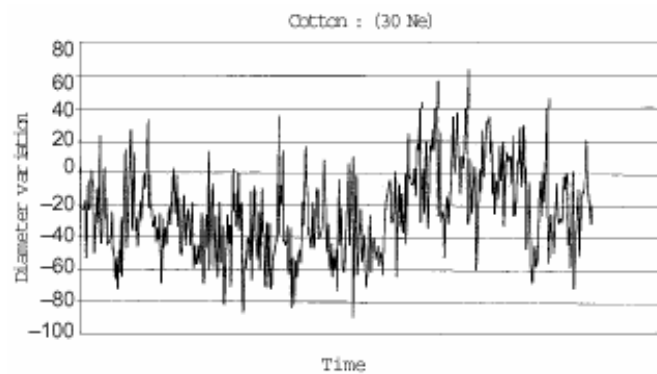


Figure 1.9. On-line measurement of cotton diameter variation on the computer screen [10]

Pinto, Monteiro, Vasconcelos, Soares and Carvalho studied on on-line measurement in a spinning frame for real-time control. They remark that measurement yarn mass in 1 mm range is utmost importance to properly evaluate the evenness, as several irregularities occur in 1 to 4 mm yarn length. The system is able to measure evenness and common faults up to four values of sensitivity. They performed several tests with different bobbins (open end yarn, ring spun yarn and filament fibers) in order to detect the influence of the linear mass. The primary goal of this project was to

analyze only cotton yarns, but in order to expand the system application field some tests were made to detect lycra yarns with small linear mass. At the moment they are working on the adaptation of the developed system to be able to detect lycra yarns and all types of yarns with less than 6 tex. The results of this study point out that the evaluation of yarn mass (bigger than 6 tex), with this approach, is feasible at least in the 4 mm range. The main goal of this project is to develop a new technique that allows the on-line measurement of 1 mm yarn mass in a spinning frame. [11,12]. Control panel software components of this study is shown in Figure 1.10.

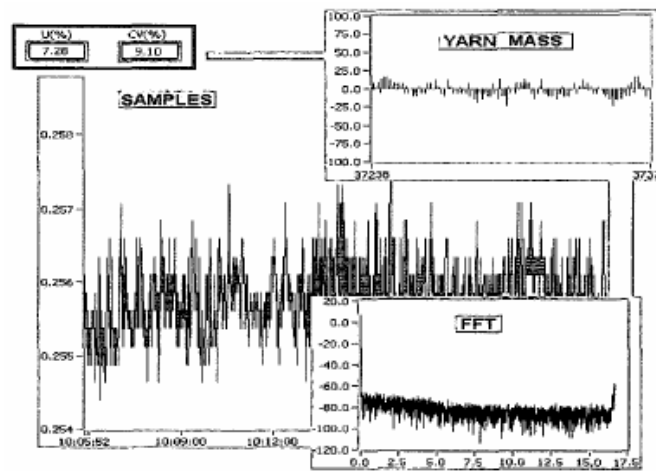


Figure 1.10. Control panel software components [11]

Jeong and Suh developed a data acquisition system as shown in Figure 1.11 to capture the analog signal directly from the Uster Tester 3. Their analyze attempted to relate the density profiles of slivers to that of the resulting rovings by separating the process variance and input variance from each product. The captured data show a linear relationship between the amplitudes of output signals and the yarn counts [13].

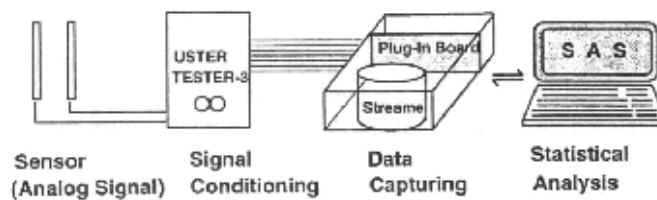
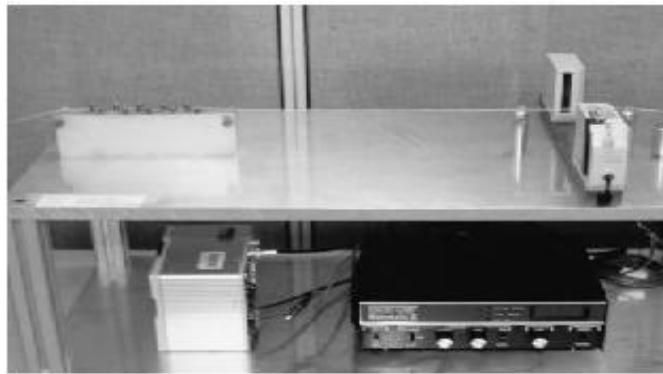


Figure 1.11. A schematic diagram of the data acquisition system [13]

Jasper, Suh and Woo studied on a project which was focused on developing an integrated, simultaneous yarn measurement system which combines optical and capacitor sensors. Two individual system for diameter and mass measurement is shown in Figure 1.12. Using the system, they studied the relationship between the mass density and diameter measurements obtained from the two types of sensors. They also analyzed and compared density profiles obtained from several spun yarns. The first objective of the study is to design and construct a new system for measurement, control, and quality maximization in spun yarn manufacturing by combining the diameter and mass density signals of yarns, which in turn would provide a superior prediction of the visual qualities of the resulting fabrics. The result has shown that the optical CV% is lower than the CV% based on mass density when the measuring field lengths are the same as shown in Figure 1.13. [14].



(a) - diameter measurement system



(b) - mass measurement system

Figure 1.12. (a,b) Two individual systems for diameter (a) and mass (b) measurements [14]

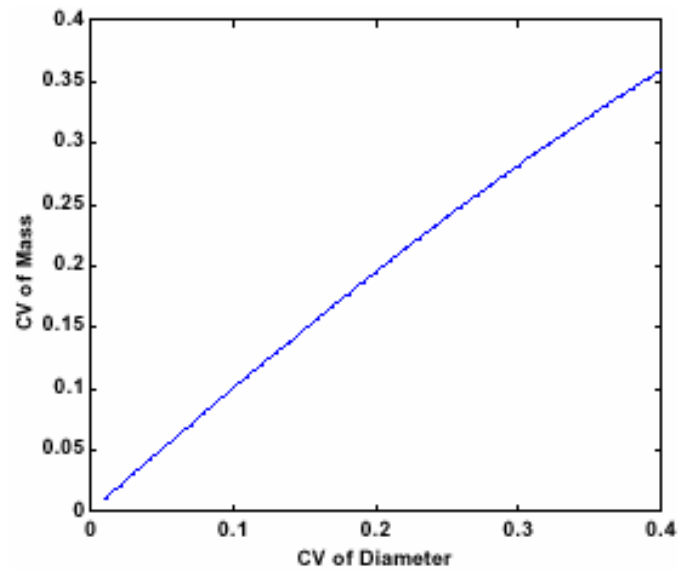


Figure 1.13. Relationship between two CV %s based on optical and mass sensors [14]

Huh and Suh studied on a project which describes a method for measuring and analyzing the cross-sectional variation of fiber bundles on the basis of a new measurement system consisting of a flying laser spot and a photoelectric sensor. The system is shown in Figure 1.14. Figure 1.15 shows a typical measurement signal obtained during the experiment. [15]

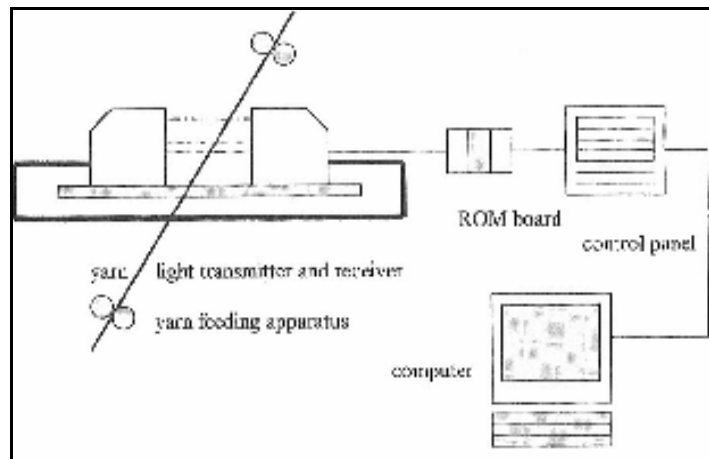


Figure 1.14. Configuration of the measuring system using laser flying spot [15]

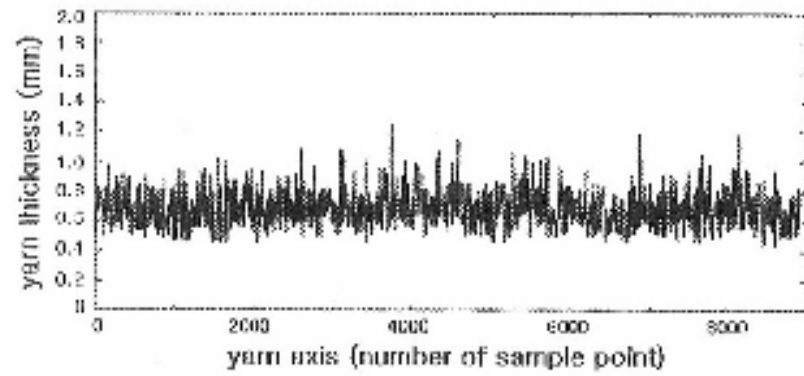


Figure 1.15. Measured signal of the yarn thickness [15]

Yarn feeding speed, m/min	Mean diameter, mm	Standard deviation of diameter, mm	CV%
0.38	0.698	0.155	22.28
5.83	0.683	0.109	15.97
10.35	0.682	0.099	14.51

Figure 1.16. Numerical results obtained from experiment [15]

Figure 1.16 contains experimental results from the same yarn sample for various yarn feeding speeds. The results show that the measuring signal delivers different yarn diameter values and their variances depending on the yarn feeding speed, which means the measured results depend on the experimental conditions. The dependence of the test results on the yarn feeding speed is given graphically in Figure 1.17.

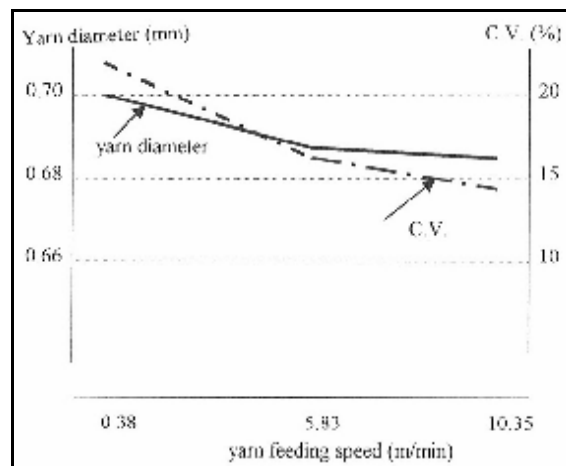


Figure 1.17. Dependence of yarn thickness on test speed [15]

Their results from the new measuring system show stable operation. The signals generated in the experiment are reproducible and trustworthy, but depend on the test condition. The mean diameter of the yarn is independent of the test condition, while the variations in yarn diameter are sensitive to the feeding speed. [15]

1.4. Structure of Thesis

Chapter 2 is named as “Basic Fiber and Yarn Characteristics”. This chapter gives detailed information about basic fiber and yarn characteristics. Fundamental properties of fiber and their influence on spinning process and end-product quality level are explained. Also basic yarn properties and their effects on properties of fabric are explained in this chapter.

Chapter 3 is named as “Quality Control”. In this chapter, the importance of quality control and examples of on-line and off-line quality control techniques applied in textile industry are mentioned. The main part of this chapter is the illustration of numerical and graphical quality parameters of yarn in detail

Chapter 4 is named as “Software”. This chapter includes usage of the designed software and how to be calculated and drawn numerical and graphical quality parameters of yarn in the algorithm of the software.

Chapter 5 is named as “Experimental Set-up and Experimental Study”. This chapter gives information about the properties of the components of the experimental set-up. At the end of this chapter experimental results measured on the designed experimental set-up, Uster Tester 4 and Premier Tester 7000 evenness testers are shown respectively.

Chapter 6 is named as “Conclusion”. This chapter includes the conclusion of the thesis and possible developments and recommendations on the experimental set-up and software are given for further study

CHAPTER 2

BASIC FIBER AND YARN CHARACTERISTICS

2.1. Introduction

The role of textile fibers for clothing, bedding and furnishing is so central to our lives that the history of fibers is almost as old as the history of our civilization. Many products that use fibers are less obvious. Traveling by car, contact with the road is through tires in which the rubber is reinforced by textile fibers. The road itself may have been laid on a geotextile foundation in which fibers are used to give the road a firmer base. Traveling by aircraft, train, bus, or ship, parts of the vehicle will also certainly be made from fiber reinforced plastics [16]. This chapter includes basic fiber and yarn characteristics.

2.2. Basic Fiber Characteristics

Fiber is a unit of matter characterized by flexibility, fineness and a high length to width ratio. The characteristics of fibers are given below;

2.2.1. Fiber fineness

Fineness is one of the most important fiber characteristics. Apart from wool and hair fibers, fiber fineness cannot be specified by reference to diameter as in the case of a steel wire, because the section is seldom circular and is thus not easily measurable. The fineness of filament fibers are specified in terms of “tex” or “dtex”, whereas, the micronaire value is used worldwide for cotton. The scale of micronaire values is as seen on Table 2.1.

Table 2.1. Scale of micronaire values

Micronaire value	Fineness
Up to 3.1	very fine
3.1 - 3.9	fine
4.0 - 4.9	medium
5.0 - 5.9	slightly coarse
above 6	coarse

2.2.1.1. The importance of fiber fineness

The fineness determines how many fibers are present in the cross-section of a yarn of given thickness. Additional fibers in the cross-section provide not only additional strength but also a better distribution in the yarn. Thirty fibers are needed at the minimum in the yarn cross-section, but there are usually over 100. One hundred is approximately the lower limit for almost all new spinning process. Fiber fineness influences primarily [18]:

- a) Spinning limit
- b) Yarn strength
- c) Handle
- d) Yarn evenness
- e) Yarn fullness
- f) Productivity
- g) Drape of the fabric product
- h) Luster

Cloth made from fine fibers or filaments has a softer and smoother ‘handle’ than an identical cloth made from coarser fibers or filaments, because the finer fibers are much softer than coarser ones. Since the yarns are more regular the cloths are more regular in appearance and held up to the light are likely to appear better covered. The cloths from the finer fibers are also likely to have a softer and more luster. Finer fibers are, of course, more easily damaged than coarser ones and for this reason they are associated with a lower resistance to abrasion in the fabric. Being also more flexible they are likewise more liable to become entangled in the little balls of fiber associated with the defect known as ‘pilling’ [2, 19].

2.2.2. Fiber length

Length is one of the more important characteristics of fibers and probably the most valuable to the spinner is the length. Staple fibers have definite length. They may have a length of 10-500 mm; however, filaments have indefinite length [16, 17].

2.2.2.1. Fiber length distribution

With staple fibers, the individual fiber length is less important than distribution of fiber lengths in a sample of fibers. Staple fiber diagrams vary for different varieties of natural fibers. Man made fibers can be cut to any length but are normally cut to a length appropriate for the processing system. They are not all cut to the same length but with some variations to avoid certain problems in spinning [16].

If the fibers of a tuft are arranged next to each other with their ends aligned and sorted according to length in a co-ordinate system, then the staple diagram as shown in Figure 2.1., the so called numerical diagram.

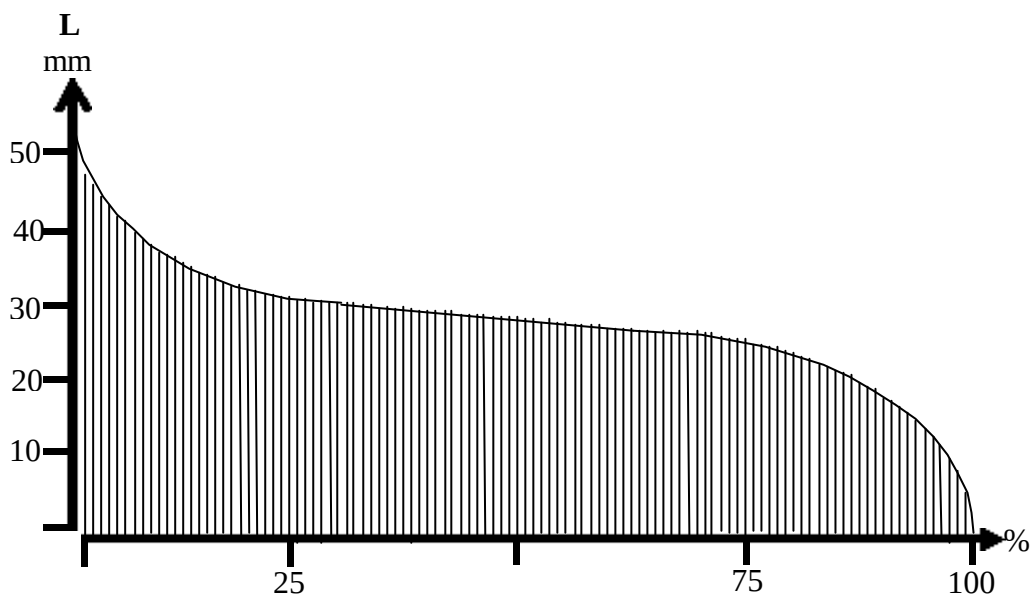


Figure 2.1. The staple diagram, numerical diagram

If the diagram is derived abstractly from the masses of the length groups, then the weight-biased diagram is obtained as shown in Figure 2.2.

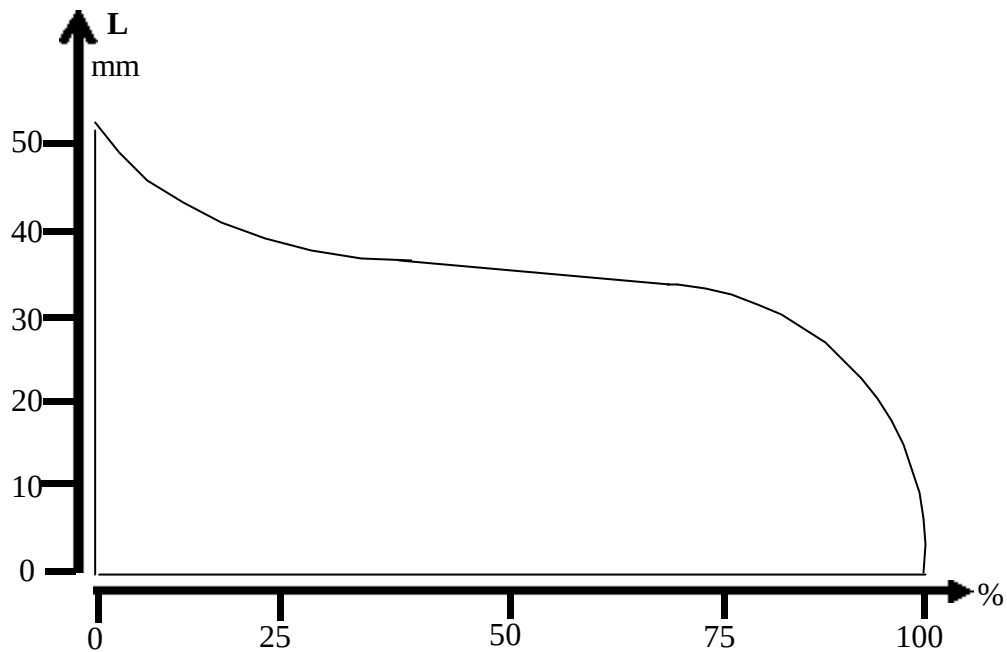


Figure 2.2. The staple diagram, weight-biased diagram

On the basis of staple length, cotton may be divided into four commonly used groupings. Fiber length classification is shown in Table 2.2.

Table 2.2. Fiber length scale of cotton

Length value in mm	Classification
Below 24.5	Short
25.5 – 29	Medium
29.0 – 32.8	Long
Up to 32.8	Extra Long

2.2.2.2. Short fiber content

It can be assumed that fibers of less than 4-5 mm will be lost in processing (as waste and fly), fibers up to 12-15 mm do not contribute to strength but only to fullness of the yarn, and only those fibers above these lengths produce the other positive characteristics in the yarn. A large proportion of short fiber also leads to strong fly contamination and thus to strain on personnel, on the machines, on the workroom, and on the air-conditioning, and also to extreme drafting difficulties. The short fiber limit has not been standardized but may settle around 12 or 12.5 mm [18].

2.2.2.3. Specification of length

From staple diagram (Figure 2.3.), it is clear that various measures of length can be derived, for example;

- a) classifying staple (trade staple)
- b) hand staple (spinner's staple)
- c) 1% staple (setting staple)
- d) 2.5% staple (setting staple)

The trade staple is the most important specification of length. It corresponds to the fiber length in the weight-biased diagram at about 25% and in the numerical diagram at about 15%

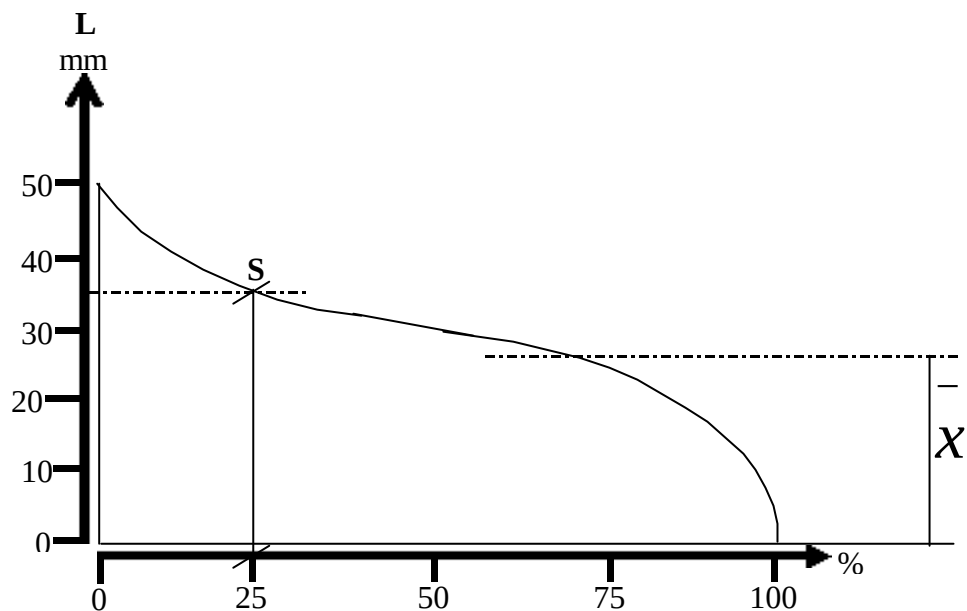


Figure 2.3. The staple diagram, weight-biased diagram

The hand staple is similar and is established by the specialist in operation. The 1% and 2.5% staples are lengths that are needed in setting machines, especially roller spacing.

2.2.2.4. The importance of fiber length

Firstly, longer fibers are easier to process. Secondly, more even yarns can be produced from them because there are less fiber ends in a given length of yarn. Thirdly, a higher strength yarn can be produced from them for the same level of

twist. Alternatively a yarn of the same strength can be produced but with a lower level of twist, thus giving a softer yarn [20].

Long-staple fibers are considered to be of finer quality because they can be made into softer, smoother stronger and more lustrous fabrics. They have a higher price and less is produced than the medium and short staple lengths [19].

2.2.3. Cotton fiber maturity

The cotton fiber consists of wall and lumen. The maturity index is dependent upon the thickness of this cell wall. Immature fibers have neither adequate strength nor adequate longitudinal stiffness. They therefore lead to

- a) Loss of yarn strength
- b) Neppiness
- c) A high proportion of short fibers
- d) Varying dye ability
- e) Processing difficulties, mainly at the card.

2.2.4. Fiber moisture content

Many fibers, particularly the natural ones, are hygroscopic in that they are able to absorb water vapor from a moist atmosphere and to give up water to a dry atmosphere.

The amount of moisture that such fibers contain strongly affects many of their most important physical properties. Furthermore because the percentage of moisture that can be retained by fibers is quite high (up to 40% with some fibers), the moisture content can have a significant effect on the mass of the material. This factor has a commercial importance in cases where material such as yarns and fibers is bought and sold by weight [20].

The amount of moisture can then be expressed as either moisture regain (MR) or moisture content (MC):

$$\text{MR} = \frac{\text{Mass of absorbed water}}{\text{Mass of dry specimen}} \times 100\% \dots\dots\dots (2.1)$$

$$MC = \frac{\text{Mass of absorbed water}}{\text{Mass of wet specimen}} \times 100\% \dots \dots \dots (2.2)$$

Figure 2.4 shows moisture regain of various fibers.

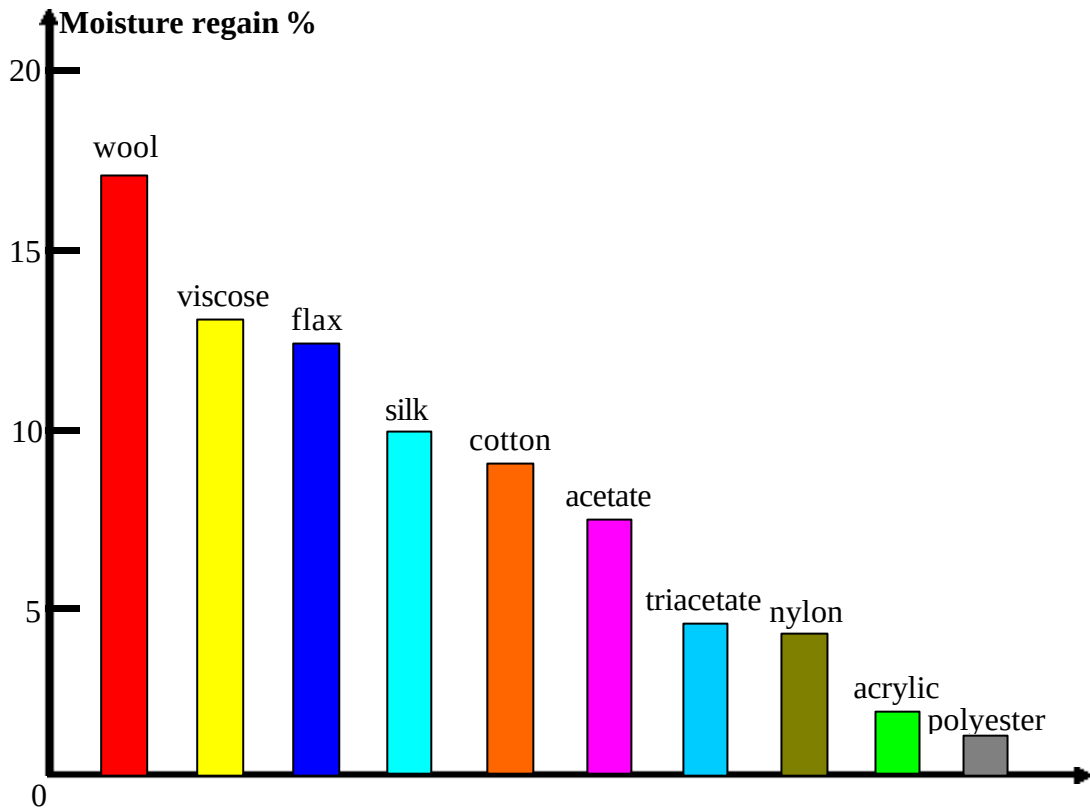


Figure 2.4. Moisture regain of fibers

2.2.4.1. Relative humidity

When considering the effects of atmospheric moisture on textile materials the important quantity is not how much moisture the air already holds, but how much more it is capable of holding. This factor governs whether fibers will lose moisture to or gain moisture from the atmosphere. The capacity of the atmosphere to hold further moisture is calculated by taking the maximum possible atmospheric moisture content at a particular temperature and working out what percentage of it has already been taken up. This quantity is known as the relative humidity (RH) of the atmosphere.

$$RH = \frac{\text{Mass of water vapour in given volume of air}}{\text{Mass of water vapor required to saturate this volume at the same temperature}} \times 100\% \dots \dots \dots (2.3)$$

The absolute humidity is defined as the weight of water present in unit volume of moist air measured in grams per cubic meter. The amount of moisture contained by

fibers that are in equilibrium with the atmosphere is dependent on the relative rather than the absolute humidity [20].

2.2.5. Fiber strength

2.2.5.1. The force – elongation curve

When you pull a fiber, it stretches and the amount of stretch is related to its resistance to force. This resistance is determined by incrementally loading or stretching the material and recording the relationship between the load or force and the amount the specimen stretches. The recording is usually in the form of a force – elongation or stress – strain curve as given in Figure 2.5.

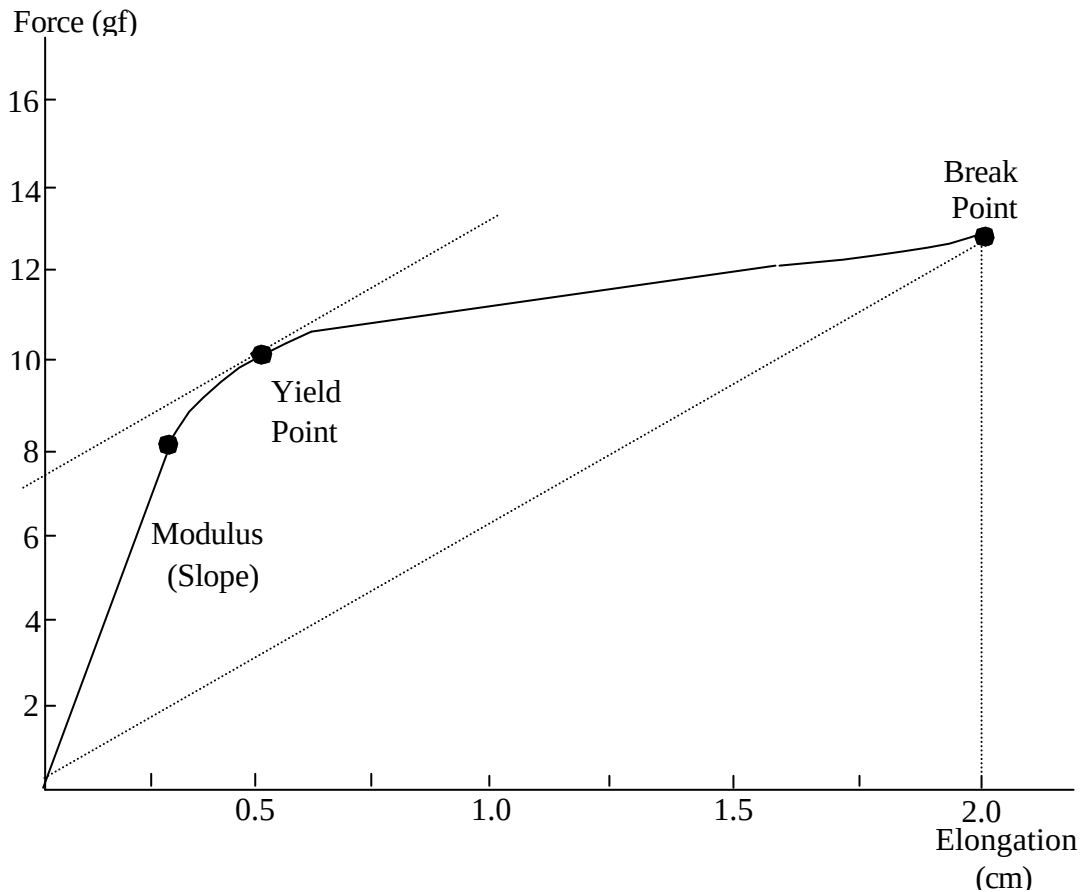


Figure 2.5. Force – elongation curve

2.2.5.2. Terms used to express fiber strength

Force and elongation are the absolute terms for the force applied and amount of stretch, respectively. Stress is the term used when the applied load or force that the material sustains is made relative to the cross-sectional area of the specimen being tested.

$$\text{Stress} = \frac{\text{Force}}{\text{Area}} \dots\dots\dots (2.4)$$

For fibers and yarns, it is difficult to determine the cross-sectional area of specimens because they are often so irregular in shape. Stress, therefore, is usually expressed as specific stress, which makes the tensile strength relative to linear density.

$$\text{Specific stress} = \frac{\text{Force}}{\text{Mass / Length}} = \frac{\text{Force}}{\text{Linear Density}} \dots\dots\dots (2.5)$$

This makes it possible to more easily compare fibers and yarns of different sizes.

Strain is the extension of a specimen relative to its initial length.

$$\text{Strain} = \frac{\text{Initial length} - \text{Final length}}{\text{Initial length}} = \frac{\text{Extension}}{\text{Initial length}} \dots\dots\dots (2.6)$$

Strain is a dimensionless value because both extension and initial length are in the same units and cancel out. However, strain values are often reported as percents [21].

Table 2.3 shows strength classification of cotton fibers measured by High Volume Instrument.

Table 2.3. HVI strength classification [24]

Degree of Strength	HVI Strength (g/tex)
Very strong	30 and above
Strong	26 – 29
Average	22-25
Intermediate	18-21
Weak	17 and below

2.2.6. Cotton fiber cleanness

Cotton contains foreign matter of various kinds [18]:

- a) **Vegetable matter:** Husk portions, seed fragments, stem fragments, leaf fragments, wood fragments.
- b) **Mineral material:** Earth, sand, ore dust picked up in transport, coal dust picked up in transport

- c) **Other foreign matter:** Metal fragments, cloth fragments, packing material (mostly polymers)
- d) **Fiber fragments:** Fiber particles (which finally make up the greater portion of the dust)

This foreign material can lead to extreme disturbances during processing.

- a) Metal parts can cause fires or damage card clothing. Cloth fragments and packing material can lead to foreign fibers in the yarn thus to its unsuitability for the intended application.
- b) Vegetable matter can lead to drafting disturbances, yarn breaks, filling up of card clothing, contaminated yarn.
- c) Mineral matter can cause deposits, high wear rates in machines.

2.3. Basic Yarn Characteristics

The structure of the yarns comprising a woven or knitted fabric is also important in product design, end-use performance, and consumer preference. The two main types of yarns are staple and filament. Staple yarns are formed by twisting together staple fibers into a continuous structure. The short fibers are held together by the frictional force between the fibers. Filament yarns are composed filament fibers that may be twisted. Twist is usually not necessary to hold the structure together because most of the fibers in these yarns are as long as the yarn. Filament yarns can be textured or bulked to change their appearance and physical properties. Properties of different yarns are presented in Figure 2.6.

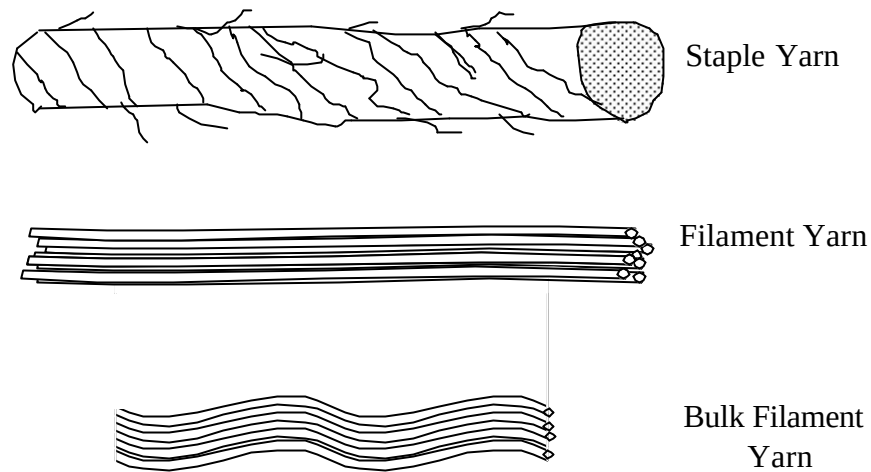


Figure 2.6. Yarn structures

Staple yarns are rougher and fuzzier than filament yarns, and can usually be distinguished by the ends of the short staple fibers that protrude from the yarn. During use and care the short fibers can be loosened from the yarn structure and entangle to form small pills of fibers on the fabric surface. Staple yarns are much more likely to form pills than are filament yarns. Filament yarns are smooth and silky, an appearance that is enhanced by the low twist. Bulkied filament yarns have the appearance of staple yarns, being rougher and less lustrous than filament yarns.

A quality factor for yarns is the number of steps involved in processing. Combed cotton and cotton-blended yarns have gone through a combing operation to remove shorter fibers and, therefore, produce a smoother yarn. Carded yarn processing omits this step and the yarns are rougher with more fiber ends protruding [21].

2.3.1. Yarn density

If a yarn were a solid cylinder, yarn density would be equal to the fiber density. In practice, there are air spaces between the fibers in spite of the pressures set up by twisting. In order to indicate the degree of fiber-packing in a yarn ‘packing fraction’, ϕ , has been defined as follows:

$$\phi = \frac{\text{Fiber volume in yarn}}{\text{Yarn volume}} \dots\dots\dots (2.7)$$

This value will also be equal to the ratio:

$$\frac{\text{Yarn density}}{\text{Fiber density}} = \frac{\rho_y}{\rho_f} \dots\dots\dots (2.8)$$

If we use the reciprocals of densities, the packing fraction will be given by:

$$\phi = \frac{\text{Specific volume of fiber}}{\text{Specific volume of yarn}} = \frac{V_f}{V_y} \dots\dots\dots (2.9)$$

The specific volume of a yarn may then be written:

$$V_y = \frac{V_f}{\phi} = \frac{\text{Specific volume of fiber}}{\text{Packing fraction}} \dots\dots\dots (2.10)$$

Packing fractions of various types of staple-fiber yarn have been published, values ranging from 0,53 for cotton to 0,61 for (1,67 dtex) rayon, an average value of around 0,57. Given a value of 0,65 for the specific volume of cotton, the specific volume of a cotton yarn may be estimated as $0,65/0,53 = 1,22$ [22].

2.3.2. Yarn fineness (count)

The thickness or diameter of a yarn is one of its most fundamental properties. However, it is not possible to measure the diameter of a yarn in any meaningful way. This is because the diameter of a yarn changes quite markedly as it is compressed. Most methods of measuring the diameter of yarn, apart from optical ones, involve compressing the yarn as part of the measurement process. Therefore the measured diameter changes with the pressure used so that there is a need for agreement on the value of pressure at which the yarn diameter is to be obtained. On the other hand optical systems of measuring yarn diameter have the problem of defining where the outer edge of the yarn lies as the surface can be rather fuzzy, having many hairs sticking out from it. Therefore the positioning of the yarn boundaries is subject to operator interpretation. Because of these problems a system of denoting the fineness of a yarn by weighing a known length of it has evolved. This quantity is known as the linear density and it can be measured with a high degree of accuracy if a sufficient length of yarn is used. There are two systems of linear density designation in use: the direct and the indirect [20].

2.3.2.1. Direct count system

The direct system of denoting linear density is based on measuring the weight per unit length of a yarn. The main systems in use are:

- a) Tex = weight in grams of 1000 meters
- b) Decitex = weight in grams of 10.000 meters
- c) Denier = weight in grams of 9000 meters

1 tex = 10 decitex.

Tex is the preferred SI unit for linear density but it is not yet in common use throughout the textile industry. In the direct system the finer the yarn, the lower is the linear density [20].

2.3.2.2. Indirect count system

The indirect system is based upon the length per unit weight of a yarn and is usually known as count because it is based on the number of hanks of a certain length which are needed to make up a fixed weight. This is the traditional system of yarn linear density measurement and each branch of the industry has its own system based on the traditional length of hank associated with the locality and the type of yarn manufactured.

The main English ones which are still used every day in the relevant parts of the industry are:

- a) Yorkshire Skeins Woolen Ny
Count = number of hanks all 256 yards long in 1 pound
- b) Worsted Count N_{W}
Count = number of hanks all 560 yards long in 1 pound
- c) Cotton Count N_{C}
Count = number of hanks all 840 yards long in 1 pound
- d) Metric count N_m
Count = number of kilometer lengths per kilogram

In the indirect system the finer the yarn, the higher the count [20].

2.3.2.3. Folded yarns

Single yarns, either from staple fiber or continuous filament, are fairly easily made and less expensive to produce. However, when two single yarns are twisted together, the thick and thin places tend to average out and consequently give a folded yarn that is more regular in thickness than either of the single components. Since the strength of a yarn is that of its weakest places, the folded yarn is relatively strong. Also, the folded yarn, if twisted in the 'S' direction on 'Z' single yarns, or 'Z' on 'S', is more lustrous, because the fibers on the surface lie nearly parallel to the yarn axis [2].

Twisting folded yarns together forms cord yarns as shown in Figure 2.7.

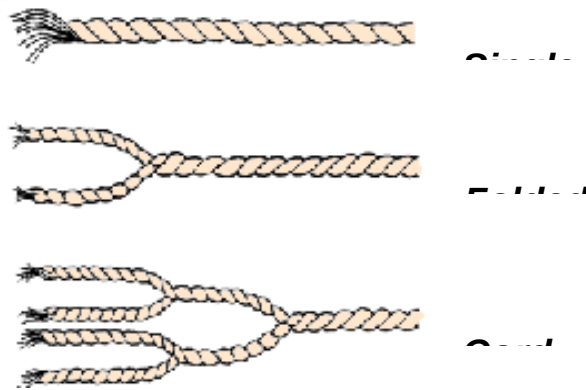


Figure 2.7. Single, folded and cord yarn [23]

In the traditional count systems a folded yarn is denoted by the count of the single yarn preceded by a number giving the number of single yarns that make up the folded yarn; for example, 2/24s worsted count implies a yarn made from two 24s count worsted yarns twisted together; 1/12s cotton count means a single 12s count cotton yarn.

In the tex system there are two possible ways of referring to folded yarns: one is based on the linear density of the constituent yarns and the other is based on the resultant linear density of the whole yarn.

In the first way the tex value of the single yarn is followed by a multiplication sign and then the number of single yarns which go to make up the folded yarn.

80 tex X 2

This indicates a yarn made from twisting together two 80 tex yarns. This type of designation is generally used with woolen yarns.

In the second way of numbering folded yarns the linear density of the whole yarn is used. This is known as the resultant linear density of the yarn and is preceded by a capital R to denote resultant. This is then followed by an oblique stroke / and the number single yarns twisted together.

R 74 tex / 2

This indicates a yarn made from twisting two yarns together which results in a final yarn whose linear density is 74 tex. This type of designation is generally used with worsted yarns [20].

2.3.3. Yarn twist

A minimal amount of twist is inserted in continuous filament yarns, just sufficient to hold the filaments together during subsequent processing. Twist is needed in the majority of staple spun yarns to bind the individual fibers together to form the yarn [16].

2.3.3.1. Twist direction

Twist can be inserted in either of two directions, clockwise or anticlockwise. The usual designation for twist direction is to use the letters S or Z. A single yarn has S twist if, when it is held in a vertical position, the fiber inclination to the axis of the yarn forms the centre of the letter S. Similarly, the yarns have Z twist if the fiber direction forms the centre of the letter Z. Two different twist directions are shown in Figure 2.8.

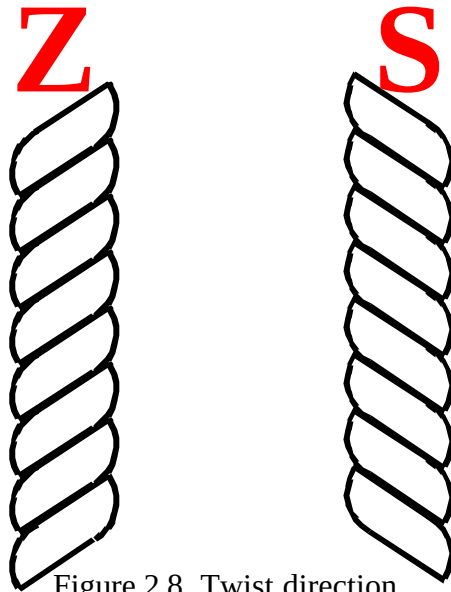


Figure 2.8. Twist direction

2.3.3.2. Twist level

Twist is usually expressed as the number of turns per unit length such as turns per meter or turns per inch. However, the ideal amount of twist varies with the yarn thickness: the thinner the yarn, the greater is the amount of twist that has to be inserted to give the same effect. Yarn can be classified by amount of twist as, very low twist, medium twist, hard twist and crepe twist [27].

2.3.3.3. The importance of yarn twist

The level of twist has other effects on yarn and fabric properties which may override the need for increased strength, including the following:

- a) **Handle:** As the twist level in a yarn is increased it becomes more compact because the fibers in it are held more tightly together, so giving a harder feel to the yarn. Furthermore the covering power of the yarn is reduced because of the decrease in the diameter of the yarn.
- b) **Moisture absorption:** A high level of twist in yarn holds the fibers together and hence restricts the access of water to the yarn interior. A low twist yarn will absorb water more readily than a high-twist one so would be used in those applications where absorbency is required.

- c) **Wearing properties:** The level of twist has effects on two aspects of wear: abrasion and pilling. A high level of twist helps to resist abrasion as the fibers can not easily be pulled out of the yarn. The same effect also helps to prevent pilling which occurs when fibers are pulled out of the fabric construction and rolled into little balls on the surface.
- d) **Aesthetic effects:** The level of twist in a yarn alters its appearance both by changing the thickness and also by altering the light-reflecting properties owing to the change in angle of the fibers [20].

2.3.4. Yarn diameter

Many textile experts contend that a yarn can not have a diameter because its cross-section is not a true circle. An examination of photographs of cross-sections lead one to agree with them but for the following discussion take the circle as a first approximation to the cross-sectional shape of a spun yarn. We shall use SI units even though a yarn diameter expressed in meters may appear out of character.

2.3.4.1. Yarn diameter formula

The length of 1 kg of C-tex yarn is:

$$L = \frac{10^6}{C} \text{ m} \dots\dots\dots (2.11)$$

Where C represents the weight (in grams) of yarn which has a length of 1 kilometer.

Let V_y be the specific volume of the yarn in cubic meters per kilogram, m^3/kg . From equation (2.11), $10^6/C$ m has a mass of 1 kg, and this has a volume of $V_y \text{ m}^3$. If d (meter) is the yarn diameter, the volume is:

$$V_y = \frac{\pi d^2}{4} \times \frac{10^6}{C} \dots\dots\dots (2.12)$$

Rearranging equation (2.12) to make d^2 the subject of the equation gives:

$$d^2 = V_y \times \frac{4}{\pi} \times \frac{C}{10^6} \dots\dots\dots (2.13)$$

Hence:

$$d = \sqrt{V_y \times C} \times \frac{1,128}{10^3} m \dots\dots\dots(2.14)$$

Since specific volume is more commonly expressed in units of cm³/g, the value of V_y in these units is 1000 times the value used in equation 2.14 and, in such a case , the numerical value of the d will need to be reduced $\sqrt{1000}$, the square-root of 1000 being used because V_y is also under a square-root sign. Furthermore, if we want d in millimeters, we must multiply the right-hand side of equation 2.14 by 1000. Hence we have:

$$d = \sqrt{V_y \times C} \times \frac{1,128}{10^3} \times \frac{1000}{\sqrt{1000}} \text{ (mm)} \dots\dots\dots(2.15)$$

$$= \sqrt{V_y \times C} \times 0,0357 \dots\dots\dots (2.16)$$

i.e.:

$$d = 0,0357 \sqrt{V_y \times \text{linear density}(\text{tex})} \text{ (mm)} \dots\dots\dots(2.17)$$

2.3.5. Yarn strength

The strength of a yarn is one of its most important characteristics, largely governing its performance in further processing. Measurement of the strength of a yarn is known as tensile testing.

Tensile testing is the loading of a yarn along its main axis as shown in Figure 2.9. A weight or load is put on the yarn which measures the load in grams, kilograms, or Newton. The breaking load is the weight at which the yarn specimen breaks. The stretch or elongation in the yarn is also measured; the extension at break is the total increase in yarn length up to the breaking load. Extension is measured in centimeters or millimeters or given as a percentage [16].



Figure 2.9. Yarn tensile testing

The load and extension can be plotted on a graph. This is known as a load/elongation curve which describes how specimen behaves from zero load and extension up to breaking point.

2.3.5.1. Practical parameters describing yarn strength

Yarn tenacity

To compare the results of tensile tests on yarns, the thickness and length of the yarn specimen must be taken in account. This will give the yarn tenacity. To compare results independently of their dimensions, units of stress and strain must be used rather than load and elongation.

Stress

Stress is used rather than load because it takes into account the thickness of the material (a thicker material has a larger cross-sectional area and should therefore be able to more load than a thinner material). Stress is the load for a given cross-sectional area, as this is difficult to measure in yarns; the specific stress is used, which is the load for a given linear density.

$$\text{Specific stress} = \frac{\text{load}}{\text{linear density}} \dots\dots\dots (2.18)$$

Typically, the units of stress are grams per tex (g/tex), or grams per decitex (g/decitex). Using the correct SI units, load is measured in Newton (N), the unit of force.

Force = mass X acceleration

Assume that acceleration due to gravity is 9.81 m s^{-2}

load (N) = mass (kg) x $9.81 \text{ (m s}^{-2})$

The SI units of specific stress are therefore Newton per tex (N tex^{-1})

Strain

Strain is used rather than elongation because this measure the increase in length as a proportion of the initial length:

$$\text{Strain} = \frac{\text{elongation (mm)}}{\text{initial length (mm)}} \dots\dots\dots (2.19)$$

Strain is a proportion and so has no units. It is sometimes quoted as the percentage extension:

$$\text{Percentage extension} = \text{strain} \times 100 \dots\dots\dots (2.20)$$

2.3.5.2. Lea and single-end yarn strength

In the quality control laboratories of many spinning mills, the strength of a lea (120 yards) of yarn is tested, this being known as lea-strength testing. A hank of yarn, 120 yards long with its ends knotted together, is placed over the hooks of the testing instrument. The bottom hook moves down at a constant rate, so loading the hank. A number of the strands of yarn in the hank will break, until the point is reached where the remaining threads cannot bear any further load. This is noted as the breaking load [28]. Figure 2.10 shows lea and single end strength testing.

For more accurate and flexible testing, single-thread strength testing is used. A load is applied to a single yarn specimen. Both breaking load and extension at break are noted. Some testing instruments will also automatically give a load elongation curve.

If the instrument is also given the necessary information - yarn linear density and specimen test length - a stress/strain curve may also be possible [16].

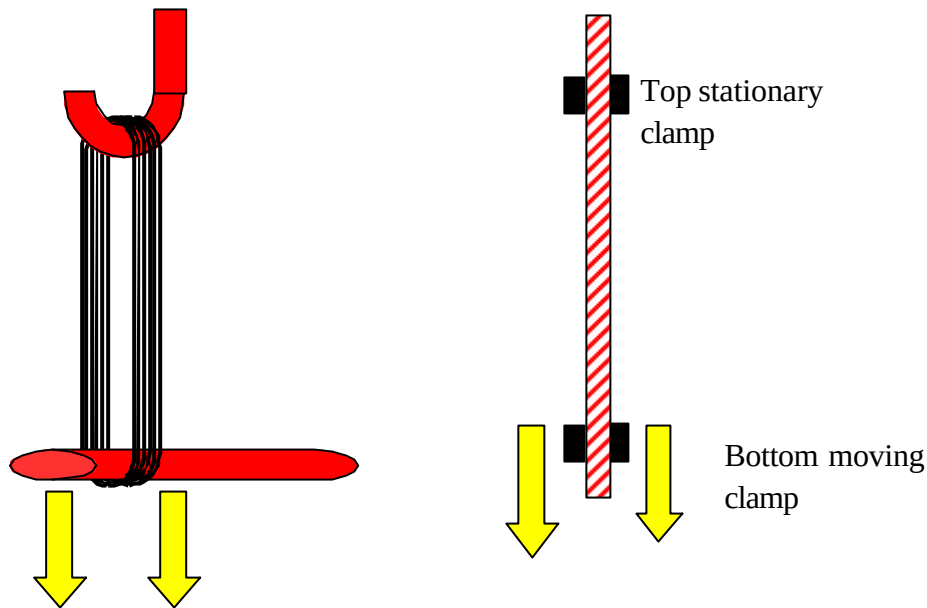


Figure 2.10. Lea and single-end strength testing

2.3.5.3. The importance of yarn strength

The level of strength required from a yarn or fabric depends on its end use. For some end uses it is the cases that the higher the strength of the materials, the better it is for its end use. This is particularly true for yarns and fabrics intended for industrial products. However, fabrics intended for household or apparel use merely need an adequate strength in order to withstand handling during production and use. It is generally the case that a higher-strength product can only be obtained by either making a heavier, stiffer fabric or by using synthetic fibers in place of natural ones. In either case changes are produced in other properties of the material, such as the stiffness and handle, which may not be desirable for a particular end use [20].

2.3.6. Yarn hairiness

Hairiness of a spun staple fiber yarn occurs because some fibers protrude from the yarn body; other fibers arch into loops, emerging from the yarn core. Fiber hairs surrounding a textile yarn may adversely affect the operations which follow spinning, such as weaving and knitting, and may influence the characteristics of the finished product. Hence, measurement of yarn hairiness has become an essential and

routine test in the textile industry. However, it is not possible to represent hairiness with a single parameter because the number of hairs and the length of hairs both vary independently. For example Figure 2.11 shows a relatively smooth yarn and Figure 2.12 a much hairier yarn. Theoretically a yarn may have a small number of long hairs or a large number of short hairs or indeed any combination in between. The problem is then which combination should be given a higher hairiness rating [23, 25].

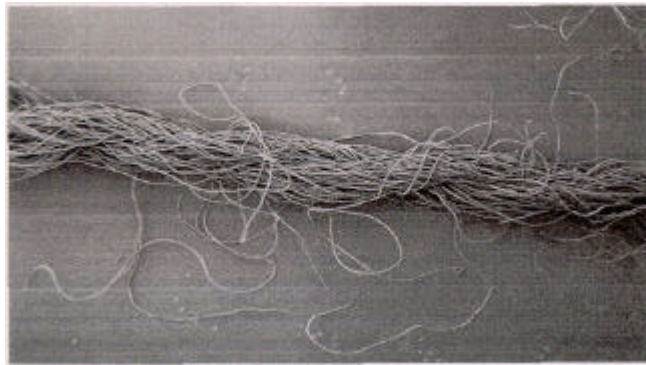


Figure 2.11. A relatively smooth yarn [20]

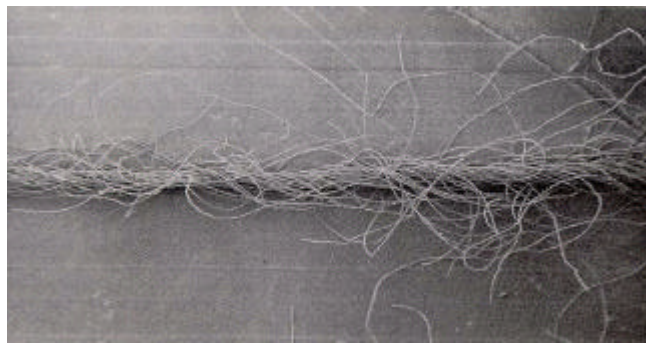


Figure 2.12. A much hairier yarn [20]

CHAPTER 3

QUALITY CONTROL

3.1. Introduction

Some form of quality control is needed at every stage of manufacture so that the finished product will be satisfactory to the customer and will hopefully lead to repeat orders.

There are several reasons for testing. Selection of raw materials would be very much a matter of luck without fiber tests to determine the characteristics of that particular batch, monitoring and control of processing conditions are essential to the quality of the end-product, research and development of processes would not take place without some way of evaluating the processes, checking of the finished product is always a good idea even though this should be unnecessary if process control is efficient, and checking against customer specifications should be done at the beginning of the run to avoid rejection of the whole order.

If a process goes out of control, much time and money can be wasted producing sub-standard material. The earlier problems can be detected, the sooner the process can be brought back under control and faulty material isolated.

Standards must be set, with limits on either side of the standard. Material that falls within the limits is allowed to pass forward to the next stage in processing. In traditional mills, this monitoring is still carried out manually by operatives at set times in the day. In mills equipped with more modern machinery, there is electronic on-line monitoring equipment which is continuously assessing the process.

If process control was perfect, there would be no need to check the final product. This is last-resort testing, as if faults are found, it is usually too late to trace them back to the processing system and too much faulty or sub-standard material has been produced. It does, however, mean that a manufacturer's reputation can be saved by picking up the faulty goods before they are dispatched to the customer [16].

3.2. Types of Quality Control

Traditionally, quality control was carried out by the “off-line” laboratory, on samples taken from the departments according to more or less systematic. This system is still fully valid for product control, but tends to be integrated, and in certain cases replaced by an “on-line”, a control carried out during the production cycle, and thus applied to the process [29].

3.2.1. Off-line quality control

Off-line techniques of quality control can be applied from the raw-material up to the finished product stage. These techniques are essentially based on testing of the representatives samples drawn from each stage, comparison of the results with the predetermined tolerance limits and taking remedial measures if the limit values exceeded [30].

The essential steps involved in these techniques are:

- a) Draw the required number of samples.
- b) Test samples.
- c) Interpret results.
- d) Adjust machines, if required.
- e) Test samples again.

3.2.2. On-line quality control

Traditional systems for off-line control, especially if they are performed in a laboratory distant from the manufacturing department, inevitably imply a delay in the corrective action, which is the more detrimental as, with modern machinery, the defective quantity produced in the meantime increases more and more stringent specification are necessary (therefore, it becomes to discover and eliminate faults that could be tolerated in the past.) [29].

On-line quality monitoring techniques are based on devices installed on the machines which monitor the product quality as well as process efficiency and produce a printed report of the processing conditions. The individual stages for optimizing plan can be checked precisely and efficiency quickly improved. Some of these devices and their companies are described below.

3.2.2.1. Auto-leveling systems

Attainment of correct yarn count at every processing stage is one of the primary aims in yarn manufacturing. Auto-leveling systems are used as early in the spinning processes as possible usually at the carding and drawing stages. Some of the on-line quality control systems which are used in textile machines are given below. Figure 3.1 shows the leveling in card machine.

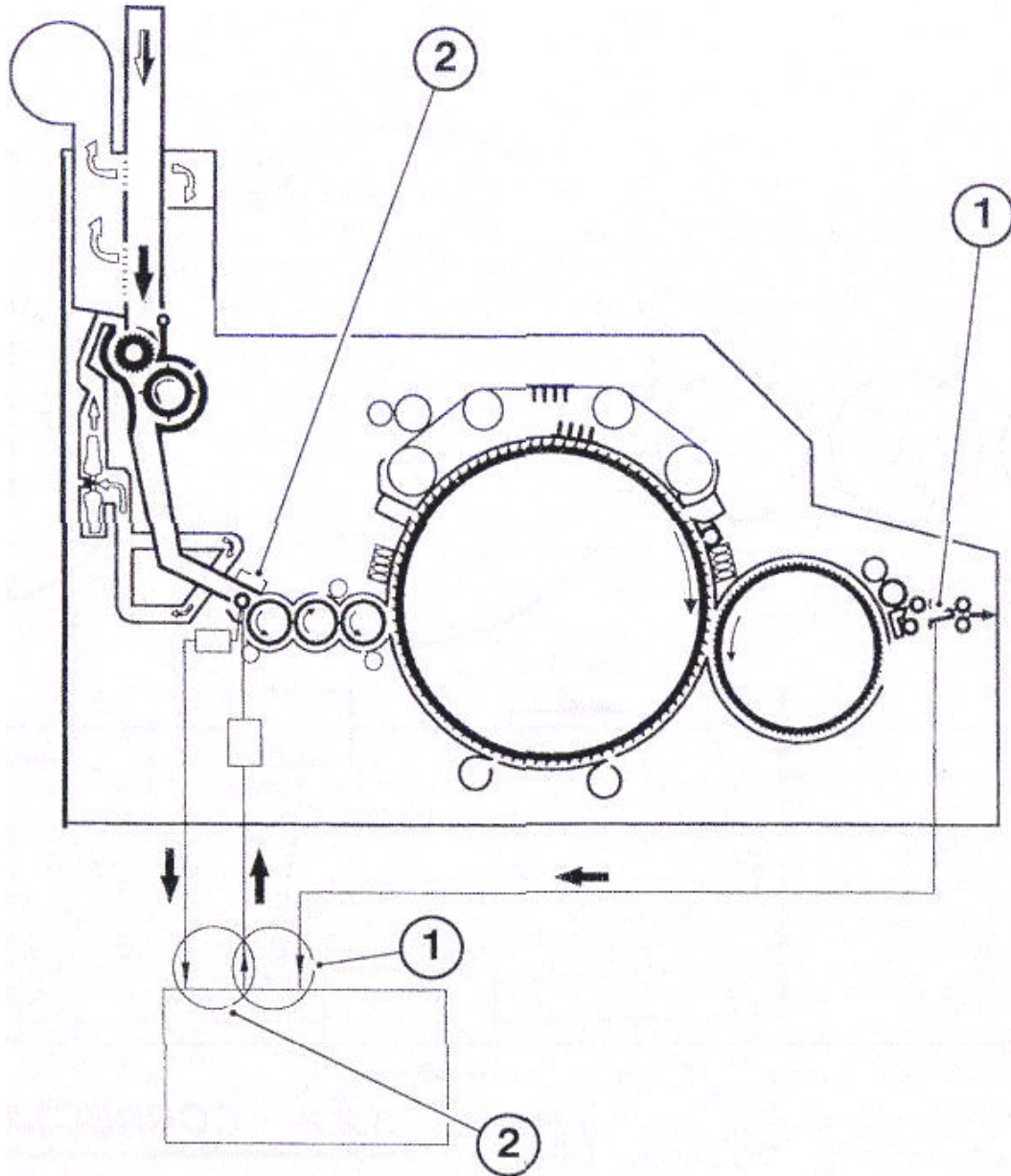


Figure 3.1. Leveling in TRÜTZSCHLER DK 903 card machine [31]

The speed control for the feed roll of the card machine is available in two different versions. Card sliver leveler (1) and tuft web control (2).

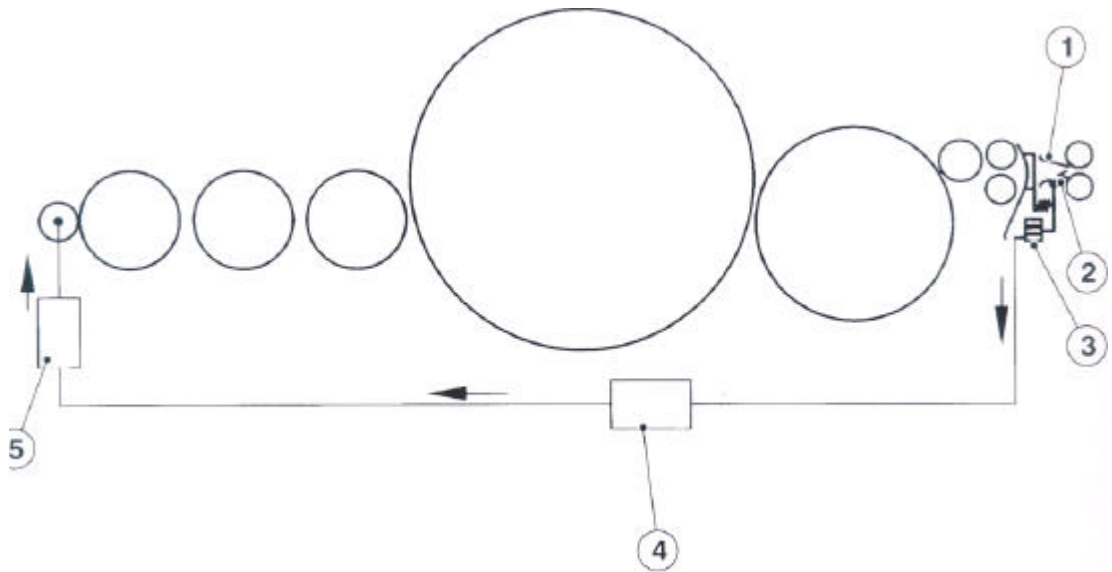


Figure 3.2. Card sliver leveler [31]

The card sliver leveler serves for a long-term leveling and monitoring of the sliver count.

Figure 3.2 shows schematic representation of the principle. In the sliver trumpet (1) of the calender unit is fitted a measuring lever (2) which is linked with a displacement detector (sensor (3)). This measuring lever measures the thickness of the card sliver and converts this information via the displacement sensor into an electrical signal, which is transmitted to the control system.

On the basis of the difference between the preselected target value and the measured actual value of the sliver count, the speed of the feed roll drive (5) is varied by a controller (4) [31].

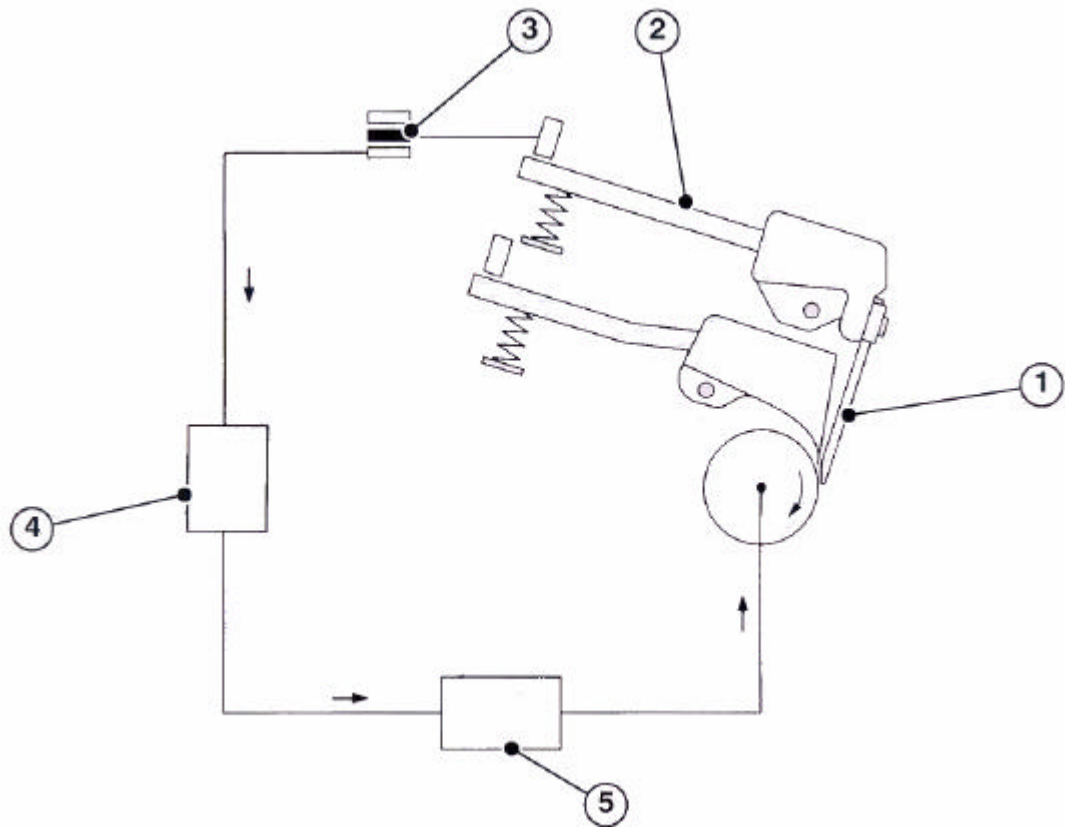


Figure 3.3. Tuft web control [31]

Figure 3.3 shows a very simple schematic representation of the principle. The tuft web control serves for leveling of the sliver count (CV-value). The leveling system works already from a sliver length of 1 m.

The thickness of the tuft web is scanned by the laminated springs (1) section by section. Variations of the thickness of the tuft web are measured via a measuring lever (2) with measuring plates and via a displacement sensor (3) are converted into electrical signals.

On the basis of the difference between the target value and the measured actual value of the sliver count, the speed of the feed roll drive (5) is varied by a controller (4) [31].

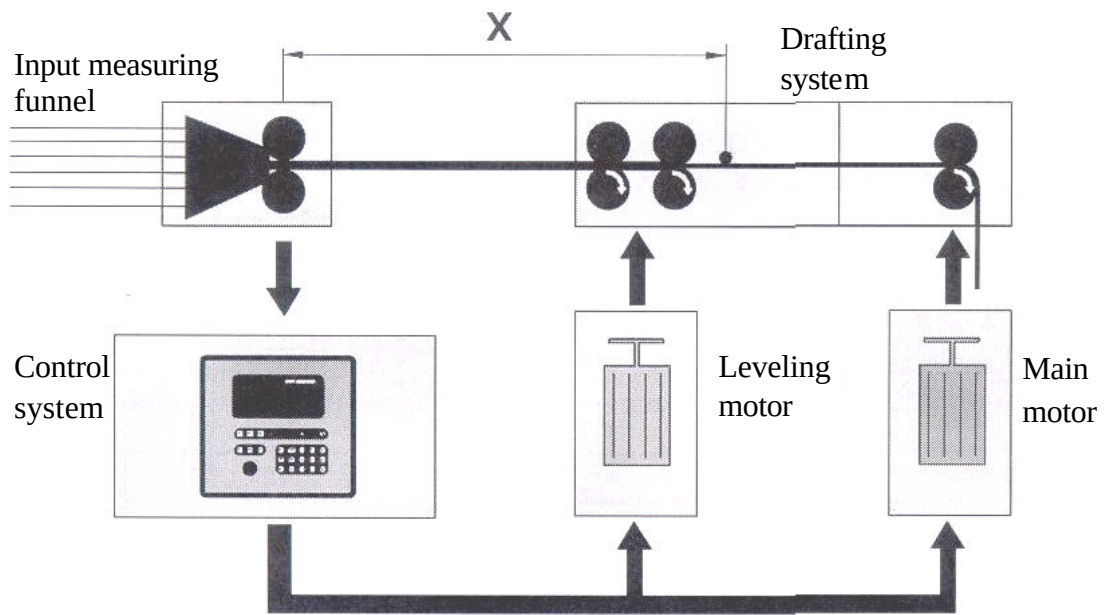


Figure 3.4. Leveling in TRÜTZSCHLER HSR 1000 draw frame machine [32]

Figure 3.4 shows the leveling in draw frame machines. The input measuring funnel serves to detect the size of a variation in the mass of the material (thick or thin place) running into the machine. The control system calculates a ΔV by which the draft must be changed in the drafting system so that the thick or thin place is leveled out.

The control system calculates a time ΔT which will pass until the thick or thin place, after leaving the input measuring funnel, has reached the drafting system.

From this result a particular time T_0 at which the thin or thick place has reached the drafting system. At the time T_0 , the draft in the drafting system will be changed by ΔV such that;

- a) In case of a thick place in the feed sliver, the draft will be slightly increased that the leveling motor will be slightly braked down.
- b) In case of a thin place in the feed sliver, the draft will be reduced that the speed of the leveling motor will be slightly increased [32].

3.2.2.2. Sliverdata

Sliverdata is an extremely useful on-line monitoring device which detects quality disturbances in the sliver with reference to the pre-set limits for sliver count, evenness, periodic faults, drafting wave faults and no of thick places per 100 m. It

generates continuous measurement of these parameters. If the limit values are exceeded machine is either stopped or an alarm is actuated depending upon the degree of deviation.

Sliverdata also detects bottlenecks and disturbances in the production processes well in time and provides details of the causes of machine stoppages which are avoided by adopting a rapid elimination procedure.

Quality and production disturbances are effectively reduced or eliminated. Defective material is not produced; process waste is reduced leading to reduction in the cost of production [33].

3.2.2.3. Ringdata

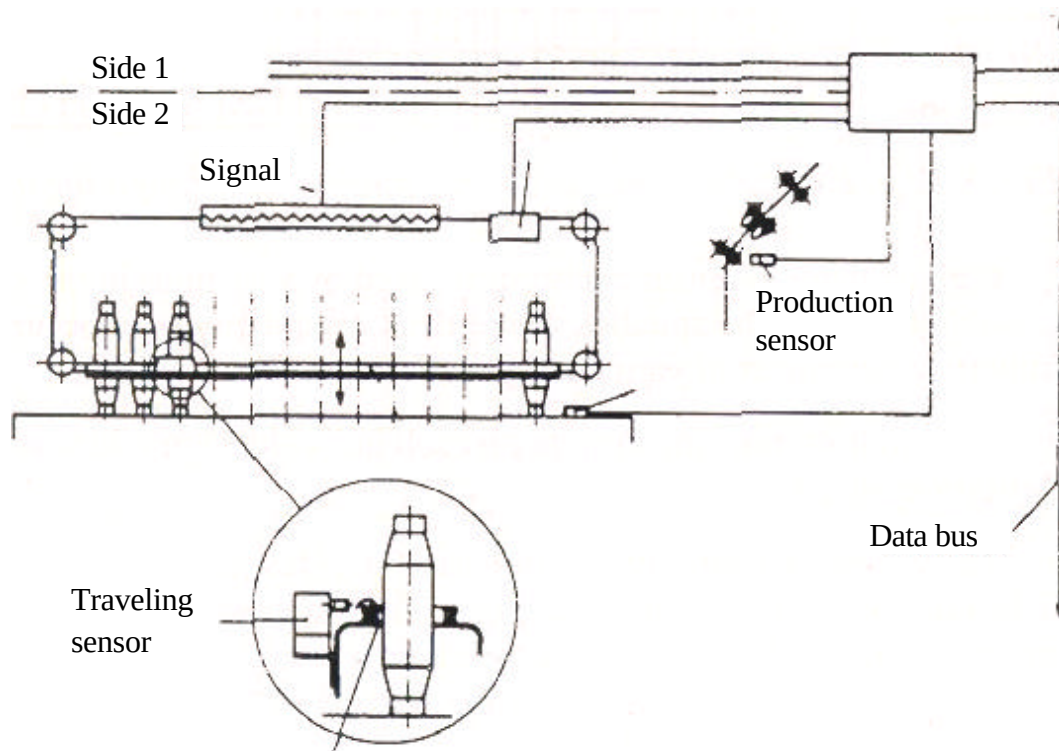


Figure 3.5. Uster Ringdata system [29]

Uster Ringdata is particularly well developed and can be applied to various types of cotton and wool ring frames, with data transmission to a central departmental unit. Moreover, as far as quality control is concerned, this device offers the very important possibility of making the analysis of the working condition on every single spindle.

Detection takes place by means of a sensor moving along the machine (at a speed of 30 cm/ sec), which notices whether the spindles are stopped or in movement via the traveler, on which it generates a magnetic field (Fig 3.5), influenced by the movement of the traveler itself. There are many possibilities for intervention [29,33]:

- The study of general spinning conditions (raw material, environmental conditions, choice of traveler, wear of the same and of other mechanical parts, spindle speed), starting from the global data regarding the frequency of broken ends;
- On the same basis, but taking into account the duration of the stops, spindle assignment and, where applicable, the incentives to be paid can be calculated;
- Thanks to the analysis of individual data, faulty spindles can be detected, which are responsible for an anomalous number of breakages (experience tends to demonstrate that a small number of spindles produce 30% of breaks). Figure 3.6 illustrates an example of the improvements which are attainable in this way;

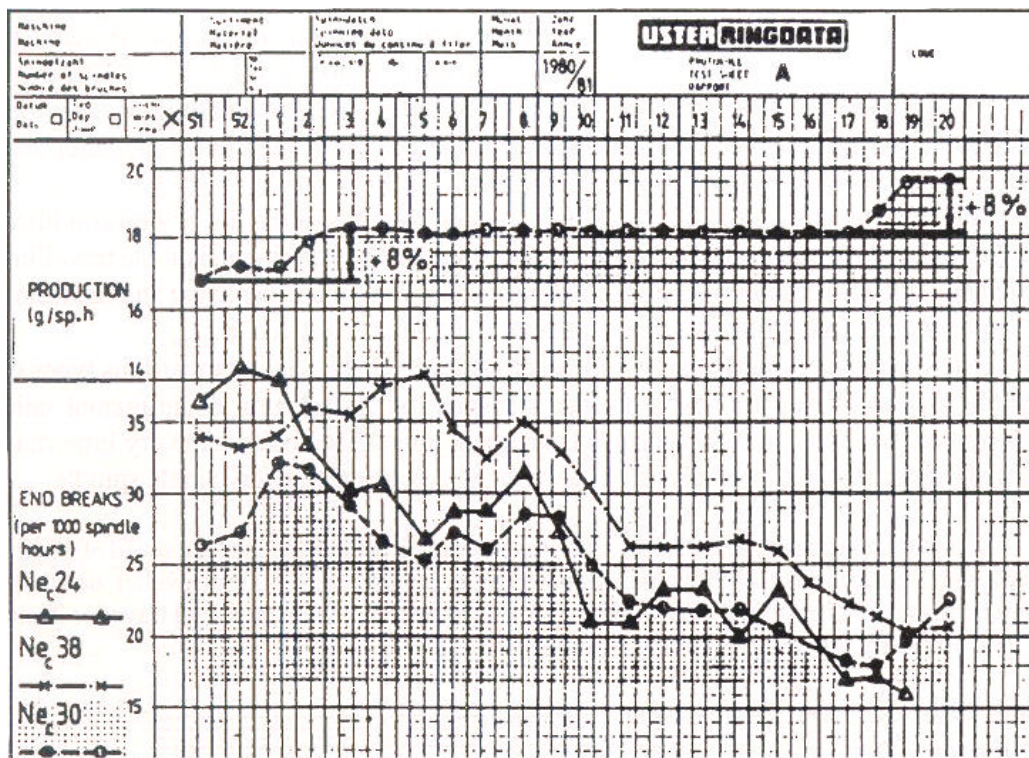


Figure 3.6. Improvements attainable through the use of Uster Ringdata [29]

Given that the sensor is also influenced by variations in the speed of the traveler, it is possible to detect the spindles where twist irregularity may occur, which also permits this important parameter of yarn quality to be kept under control.

3.2.2.4. Ring eye 5000

Ring Eye 5000 is the tool designed to derive the maximum out of the available resources. Ring Eye 5000 helps in achieving this by round-the-clock monitoring of spindle wise end breaks and speed, spindles with repeated breaks, spindles with speed deviation and by providing a history and summary of production and stops (Figure 3.7) [34].

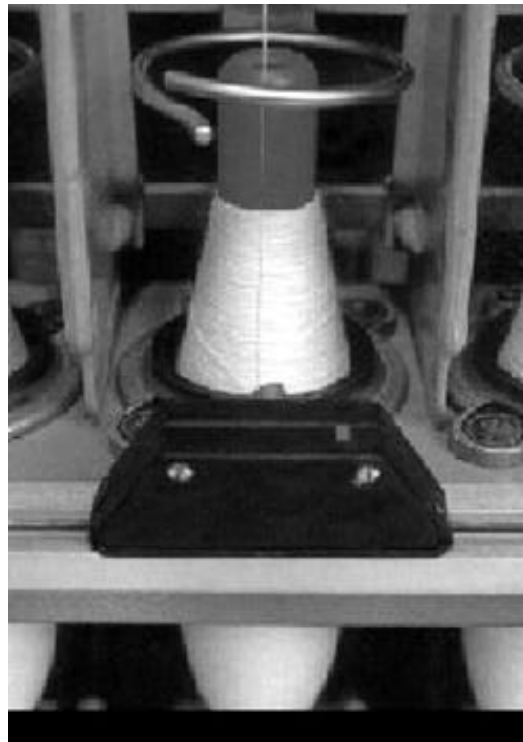


Figure 3.7. Ring Eye 5000[23]

3.2.2.5. Opti spin

With Opti Spin, BARCO offers a detector for each individual ring spindle, allowing accurate recording of the spindle speed and real-time detection of yarn breakages. The stops are always assigned to the correct spindle, regardless the length of the machine.

Interfaces are available to the speed inverter of the ring frame, allowing to increase the speed in case the ends down level remains below a defined threshold. As a result, an optimum and consistent quality level is achieved at maximum efficiency.

All detectors are connected to a PC-based central unit. All information concerning production, efficiency, ends down and slipping spindles is available on the display or can be printed out on an external printer. Connected to BARCO's Spin Master production management system, data from all machines is centralized in one data base [35].

The Opti Spin detector is installed right below the eyelet (Figure 3.8). It consists of a photo receiver facing a light emitting diode. During each revolution, the yarn balloon interrupts the light beam twice. The time between two successive interruptions serves as the basis for the calculation of the balloon speed, while the amount of light obstructed during the interruption is used as a rough diameter measure.

The functionalities of Opti Spin are;

- a) Accurate real time spindle speed detection allowing identification of slipping spindles.
- b) Indication of twist level based on spindle speed and delivery speed.
- c) Immediate ends down detection, including detection of raffles.
- d) Classification of yarn breakages during up or down movement of the ring rail and exact location in the bobbin build-up.
- e) Continuous yarn diameter estimation allowing detection of additional sliver or wrapping on draft cylinder.
- f) Flagging of problem spindles with section lights and lamp tree.
- g) Monitoring: produced weight, efficiencies and down time analysis.

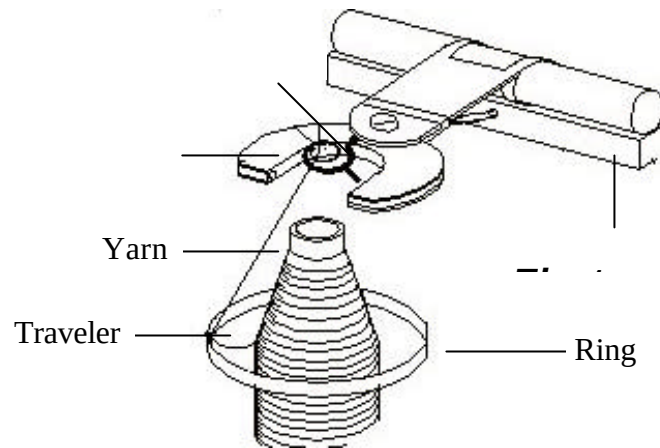


Figure 3.8. An Opti-Spin [23]

These measurement devices, which are explained above, ring data, ring eye, and Opti Spin, are used in ring spinning machines. These equipments are generally used for recording spindle revolution, production quantity, twist number, and the amount of yarn breakages. One of the disadvantages of these devices is that they can not measure on-line evenness control.

Yarn evenness is the most important parameter of quality. It affects directly all property of yarn. Mechanical, drawing and raw material faults cause evenness. These faults that occur in the yarn affect the yarn strength, yarn appearance and yarn quality.

It is very important to identify the yarn evenness for quality control. So, yarn evenness tester is the most important device in yarn quality control laboratory. In a yarn mill, quality control for evenness of yarn is performed by random selection of 5 bobbins from each machine every day. If there is a fault in these bobbins which are taken randomly, some causes are sought for. Therefore, this quality control can not be reliable. For example; if there is a fault except the chosen bobbins or if it occurs some faults that caused raw material after chosen the bobbins, until next measurement yarn will be manufactured defectively. As a result, not only time but also material is lost.

In order to prevent these problems, yarn evenness must be controlled during the production. On-line evenness control can be applied each spindle separately in a short time.

This work aims the design of a software to analyze mass variations of ring spun yarns, calculations of quality parameters and their graphical representation.

This study, in fact, is a continuation of a previous Ms. study which is named as “On-line quality control of spun yarns” completed at January 2003. For that study, an experimental set-up was prepared and on-line measurement performed, but calculation of quality parameters and their graphical representations were not done. Besides this, there were some differences between actual and measured values of mass variations of the yarns because of sensitivity of the sensors used. The study may be divided into following steps;

- a) Numerical calculations of quality parameters of these yarns such as: unevenness (U_m %), coefficient of variation (CV_m %) and spectrogram.
- d) Graphical representation of these parameters. This step requires the design of a computer software that is the main part of the study.
- e) Modification on the readily available ring spinning machine to obtain more accurate data and on line measurements of mass variations for different yarns as sample tests.

In this study a software which performs the first and the second tasks explained above was designed. In this chapter numerical and graphical quality parameters of yarn were explained.

3.3. Yarn Faults

The task of a spinner of staple fibers, in particular natural fibers, is to transform a mass of millions of individual fibers with variable properties, tangled and containing unwanted foreign matter, into a yarn characterized by uniformity of weight per unit length, diameter, turns per inch, color, strength and so on. Most of these characteristics are interrelated and a detailed analysis of any of these parameters would give us a fair idea about the extent to which a yarn is regular or irregular. However, the approach which can be considered to be universal and which has found popularity over the years is to consider the variation in weight per unit length.

Suppose we had a strand of material and cut it up into short pieces of equal length. The weight of each consecutive length could be found and plotted on a graph in a manner similar to that as shown in Figure 3.9. By joining the points, a trace is produced; this shows the way in which the weight per unit length varies about a central or mean value [16, 36].

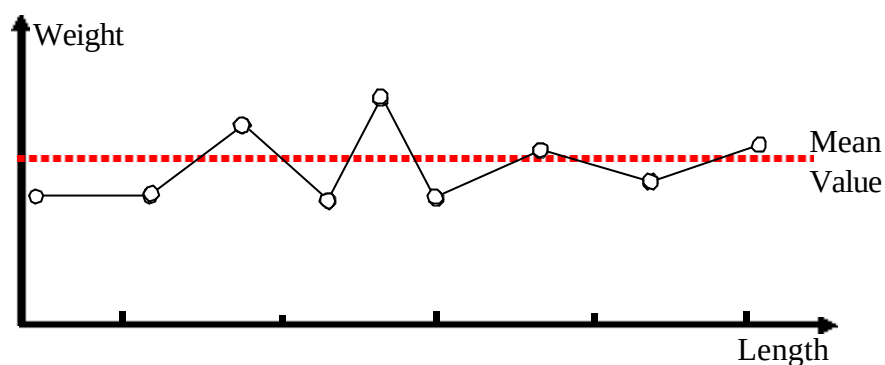


Figure 3.9. Variation in weight per unit length

3.3.1. Categories of yarn faults

A yarn which is not uniform is said to be irregular or to contain yarn defects or faults. These faults vary in their cross-sectional size and length. Figure 3.10 shows a figure of fault cross-sectional size against fault length.

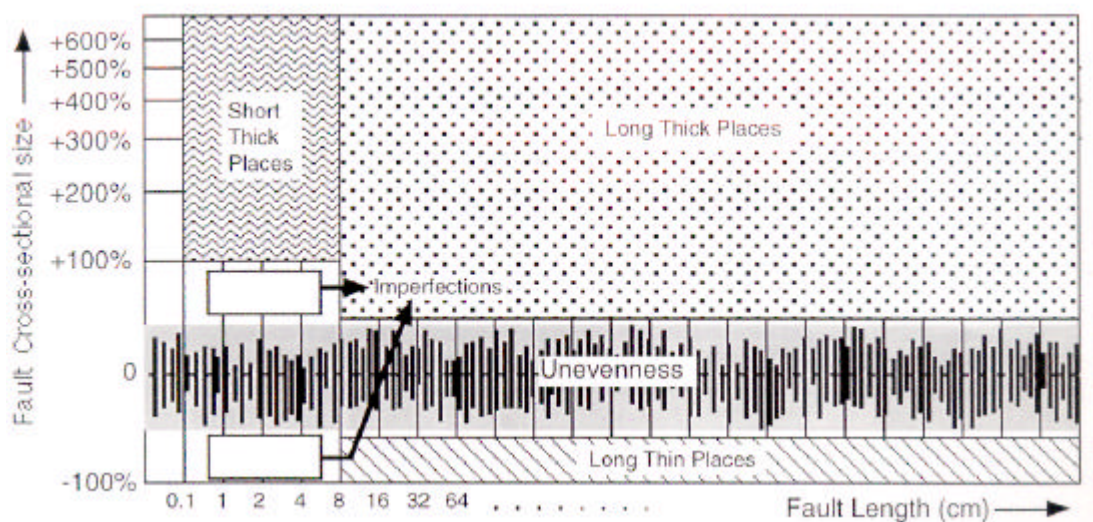


Figure 3.10. Yarn faults [36]

In the above figure, three distinct categories of yarn faults are represented based on their size, length and their frequency of occurrence.

- a) Unevenness or Irregularity.
- b) Imperfections.
- c) Objectionable yarn faults.

The definition of these faults, their relative importance, and methods of evaluation are discussed in some detail in the following sections.

3.3.1.1. “Unevenness” or “Irregularity”

The mass per unit length variation due to variation in fiber assembly is generally known as ‘Irregularity’ or ‘Unevenness’ (in practice they are called U_m % or CV_m % value).

In all staple spun material (yarn, rovings & slivers) the fiber distribution along the material varies. For example, if a yarn is cut at a number of places there is always a variation in the number of fibers present in the cross-sections. Consequently, a change in the cross section of the material within about $\pm 40\%$ is always present. This variation is also affected by fiber fineness, fiber fineness variations, and material type. Even in an ideal fiber distribution, as in the case of a continuous filament yarn, though small, there exists certain irregularity because of fiber fineness variations.

It is the skill of the spinner to arrange all machine settings in such a way that all fibers are spread as even as possible over the length of the material [36, 28].

3.3.1.2. Imperfections

Spun yarns from staple fibers contain ‘imperfections’. They are also referred to as frequently occurring yarn faults. They can be subdivided into three groups; thin places, thick places, and neps. These imperfections, although lying, in general, within the limit of $\pm 100\%$, are normally few in number and must therefore be counted separately rather than grouped with the irregularity value U_m % which they hardly influence. Normally, these imperfections range from a cross-sectional size of $+30\%$ to 100% based on the mean yarn cross-section with reference to the thick places and from -30% to -70% with reference to the thin places. The neps are measured based on a length of 1 mm. The length of the thicker places and thinner places is usually in the range of 1.5 times the staple length of the fibers in the yarn. These imperfections

are determined according to number per 1000 meters or yards or a frequency figure. These imperfections are occurred from raw material or damaged machine parts [36, 28].

3.3.1.3. Objectionable yarn faults

If one now considers faults larger than +100% based on the mean yarn cross-section, one moves into the range of ‘Yarn Faults’ and correspondingly a further reduction in the frequency. Yarn faults have sizes from +100% and larger and lengths of 1 mm and longer.

Their frequency is always referred to in terms of number per 100 kilometers of yarn. The long thick places (spinner’s doubles) and the long thin places are extremely seldom-occurring, so that they are hardly referred to by means of a frequency figure.

Of the type of faults discussed above, an ‘evenness tester’ is used to estimate the first two - unevenness and imperfections, but the software designed for this thesis is capable of detecting objectionable long faults which are especially cleared in winding section by yarn clearers.

3.3.2. The importance of evenness testing

Textile yarns may possess non-uniformity in a variety of properties, such as twist, bulk, strength, thickness, or fineness along their lengths. Such variations are inevitable because they arise from the fundamental nature and properties of the textile fibers, both natural and man-made, and their arrangements to form yarns. The term, ‘yarn evenness’, is usually used to describe variations in fineness. This may be measured in terms of variations in mass per unit length. However, yarns produced from different fibers by different techniques and processes have very different characteristics that require quantifying [37].

Irregularity can adversely affect many of the properties of textile materials. The most obvious consequence of yarn evenness is the variation of strength along the yarn. If the average mass per unit length of two yarns is equal, but one yarn is less regular than the other, it is clear that the more even yarn will be the stronger of the two. The uneven one should have more thin regions than the even one as a result of irregularity, since the average linear density is the same. Thus, an irregular yarn will

tend to break more easily during spinning, winding, weaving, knitting, or any other process where stress is applied.

Woven fabrics tend to show bars across the width of the cloth due to yarn irregularity. This effect can be reduced or eliminated by weft mixing at the loom. This is using yarn alternately from different packages to form the weft. If the irregularity is relatively short and frequent, however, weft mixing will have no beneficial effect.

Knitted fabrics are the most susceptible to yarn irregularities, that is, they are most noticeable in knitted fabrics, particularly in weft knitted single jersey fabrics. Carpets will display streaks due to yarn irregularity.

Twist tends to be higher at thin places in the yarn. When a dye or finish is applied to the fabric, penetration is less in areas of higher twist, which emphasizes the yarn fault.

Fabric weight uniformity is dependent on yarn regularity. If the yarn weight per unit length varies, the cloth weight will vary. Weight uniformity is essential in fabrics for paper making and for filters [16].

3.3.2.1. Principle of measurement

Yarn evenness is measured by various methods. The most commonly used methods are capacitive methods which detect the variations in mass per unit length placed in a field of an electrode. Optical methods use the principle of a silhouette to obtain a reading, usually from the shadow of the yarn, the area of which is taken to be proportional to the mass of the yarn specimen.

The cutting and weighing method is in fact a technique used in the measurement of irregularity in certain departments of a spinning mill, but it has the disadvantage of being slow and laborious.

The modern evenness testers estimate the level of unevenness in a yarn, roving or sliver by measuring the mass variations along the length using the universally renowned 'Capacitance Principle' (Figure 3.11).

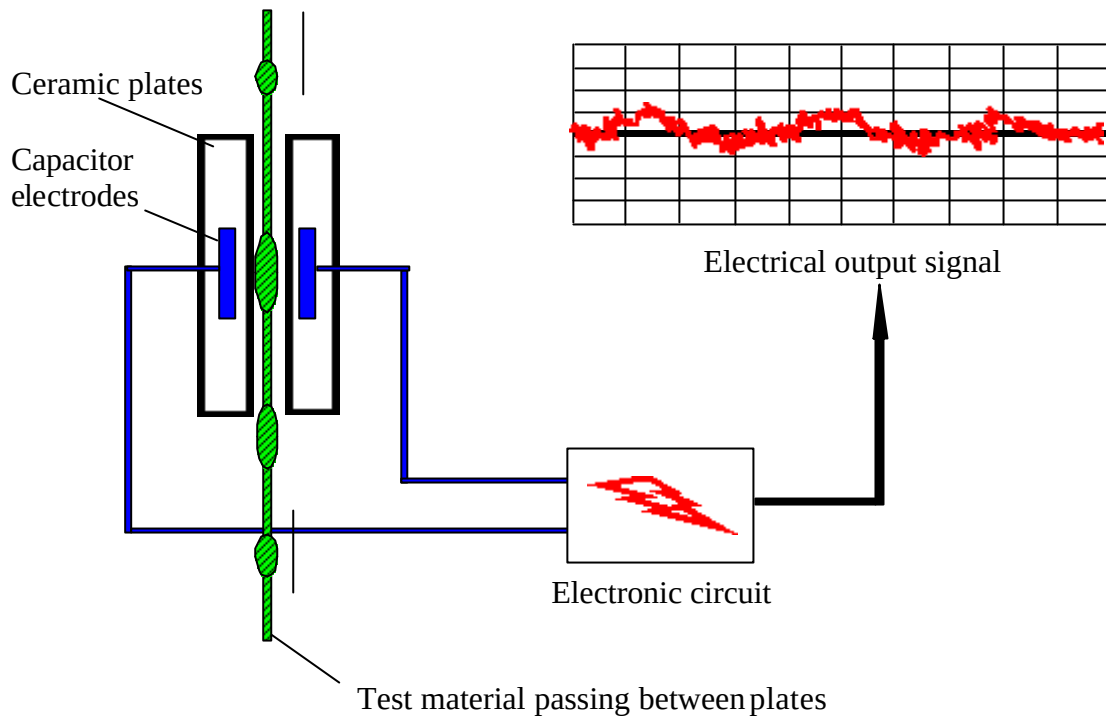


Figure 3.11. Capacitive measuring system

A high-frequency electric field is generated in the sensor slot between a pair of capacitor plates. If the mass between the capacitor plates changes, the electrical signal is altered and the output signal of the sensor changes accordingly. The result is an electrical signal variation proportional to the mass variation of the test material passing through. This analog signal is then converted into a digital signal, stored and processed directly by the computer [38].

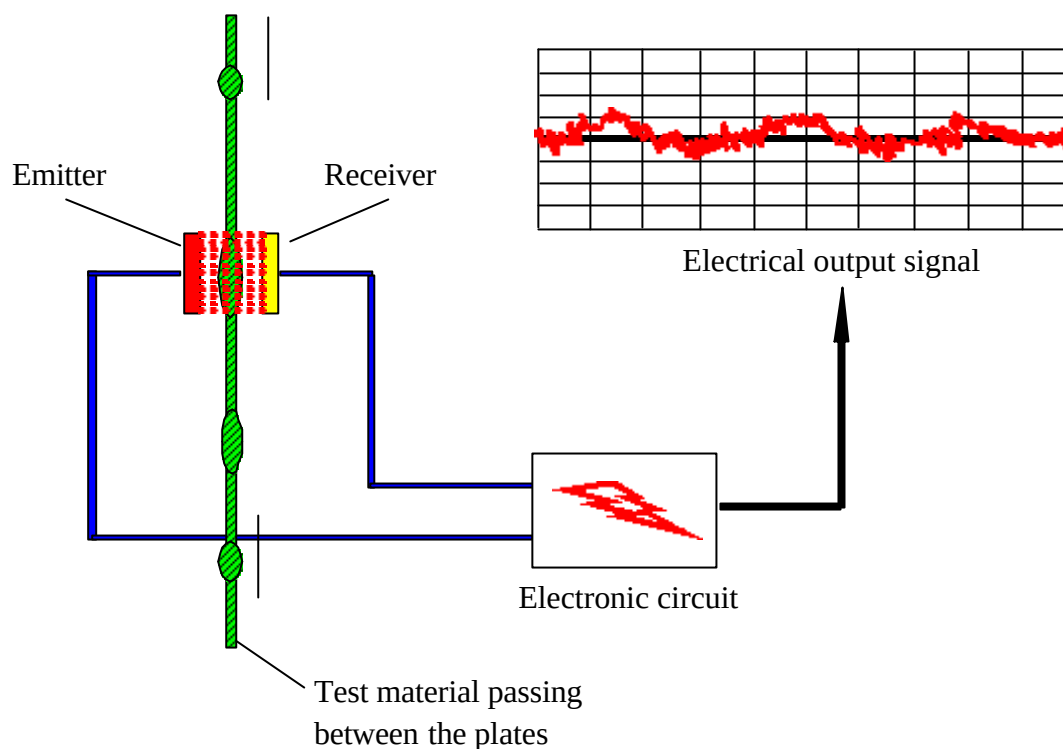


Figure 3.12. Optical measuring system

In optical measuring system (Figure 3.12), the yarn to be detected passes between the light source on one side and the receiver on the other side. The light emitted by emitter is received by receiver. The quantity of light sensed by receiver determines the changing in yarn mass.

3.3.3. Numerical estimates of the mass variations

A graphical representation of the mass variation as shown in Figure 3.9 gives a general idea about how uniform the yarn is. However, minor differences in irregularity between samples are very difficult to be identified with such graphical plots. Further, if variations of different types such as short term variations, long term variations, etc. need to be studied, one has to look at entirely different graphs and that too longer and longer lengths which becomes too laborious. For this purpose, numerical values which accurately represent the extent or mass variations are essential [36].

If a strand of material is cut up into short equal lengths, the weight of each consecutive length could be found and plotted on a graph. By joining the points a

trace is produced. This shows the way in which the weight per unit length varies about the mean value.

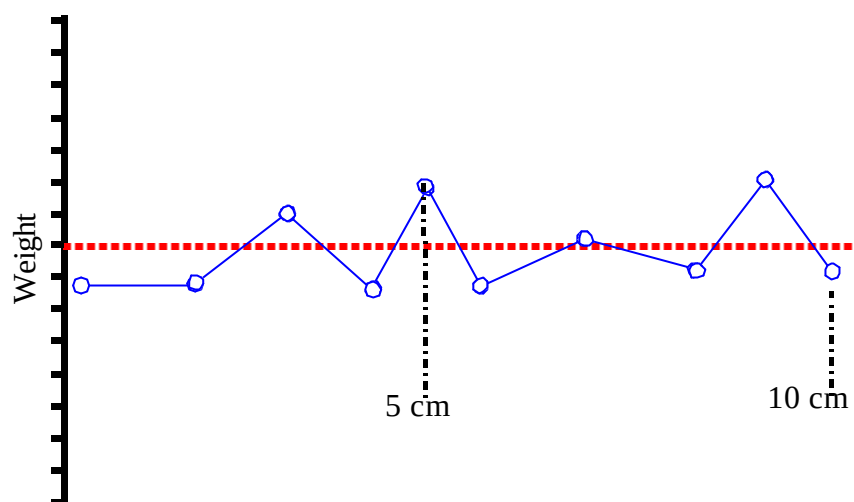


Figure 3.13. Weight of consecutive 1 cm lengths

Figure 3.13 gives some idea of regularity, but it would be difficult to compare different yarns using a diagram alone. Using statistics, a number can be calculated that represents how even the material is.

3.3.3.1. Unevenness (Percentage mean deviation) U_m %

The unevenness is the most common parameter used to express mass variations in a strand of fibers. In simple terms, it is variation in the linear density of a continuous strand or portion of a strand.

Mathematical representation

The deviations of individual results from the mean result can be found. The mean deviation can be calculated and the percentage mean deviation (PMD) derived and used as a measure of irregularity. The higher the mean deviation (and so the PMD), the more the material is straying from the middle line. The higher the number is, the more irregular the material is.

All the numbers in the first column of Table 3.1 are weights of one centimeter of yarn. These have then been totaled at the base of the column and the mean value found by dividing this sum by the number of results:

$$\frac{3.5}{10} = 0.35$$

The second column shows by how much each individual result is different from this mean value of 0.35. Because we are after the difference between the mean and individual result, the sign - plus or minus does not matter and so is left out. Again, the sum of all these differences is at the base of the second column (0.38).

The mean deviation is then found by dividing the sum of the deviations by the number of deviations:

$$\text{mean deviation} = \frac{\text{sum of deviations}}{\text{number of results}} = \frac{0.38}{10} = 0.038 \dots\dots\dots (3.1)$$

This number on its own is difficult to compare with other mean deviations if we have yarns of different tex values. For ease of comparison, the mean deviation is expressed as a percentage by dividing by the mean value:

$$\text{percentage mean deviation} = \frac{\text{mean deviation}}{\text{mean}} \times 100 \dots\dots\dots (3.2)$$

$$\text{Percentage of mean deviation} = \frac{0.038}{0.35} \times 100 = 10.86 \% \dots\dots\dots (3.3)$$

Table 3.1. Calculating deviation from the mean

Yarn weight (mg/cm-(x))	Deviation from the mean($x - \bar{x}$)
0.37	0.02
0.32	0.03
0.34	0.01
0.39	0.04
0.31	0.04
0.41	0.06
0.33	0.02
0.30	0.05
0.42	0.07
0.31	0.04
Sum x = 3.50	Sum of deviations = 0.38
Mean $\bar{x}$ = 0.35	

Graphical representation

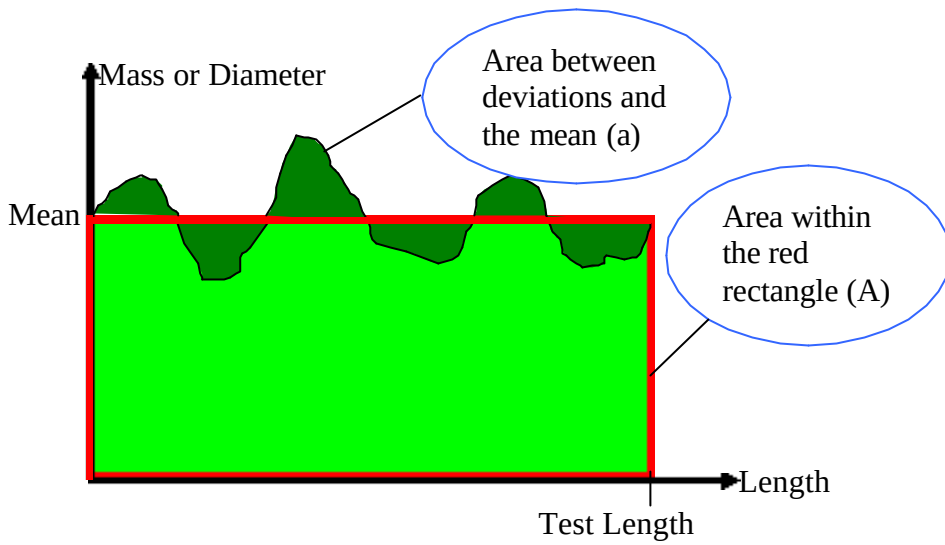


Figure 3.14. Graphical representation of unevenness

$$\boxed{U_m = \frac{a}{A}} \quad \text{————} \quad \boxed{U_m = \frac{a}{A} \times 100} \dots\dots\dots (3.4)$$

The unevenness U_m can be represented by Figure 3.14. The unevenness U_m is the ratio between the dark area 'a' and the area 'A' enclosed by the red rectangle.

3.3.3.2. Coefficient of variation CV_m %

Mathematical representation

To calculate coefficient of variation firstly standard deviation must be calculated (Table 3.2). As for the mean deviation the individual results are added up and the mean calculated. The second column is the individual result minus the mean value. The third column is the deviations squared, and remember that the sign plus or minus disappears when squared. These squared deviations are then totaled at the foot of the column (0.0176). The variance is found by dividing the sum of the squares by the number of results minus 1:

$$\text{variance} = \frac{0.0176}{(10-1)} = \frac{0.0176}{9} = 0.001956 \dots\dots\dots (3.5)$$

Table 3.2. Calculating deviation from the mean

Yarn weight (mg cm - (x))	Deviation from the mean (x + / - / $\bar{x}$)	Deviation ²
0.37	+0.02	0.0004
0.32	-0.03	0.0009
0.34	-0.01	0.0001
0.39	+0.04	0.0016
0.31	-0.04	0.0016
0.41	+0.06	0.0036
0.33	-0.02	0.0004
0.30	-0.05	0.0025
0.42	+0.07	0.0049
0.31	-0.04	0.0016
Sum x = 3.50		Sum of deviations ² = 0.0176
Mean $\bar{x}$ = 0.35		

The standard deviation is the square root of the variance:

$$\text{Standard deviation} = \sqrt{0.001956} = 0.0442 \dots \dots \dots (3.6)$$

The problem with the standard deviation is that you cannot compare yarns of different linear densities. To do this, the standard deviation must be related to the mean result. This is then known as the coefficient of variation.

$$CV_m \% = \frac{s}{\bar{x}} \times 100 \dots \dots \dots (3.7)$$

Where s = standard deviation $\bar{x}$ = sample mean result

Using the figures from Table 3.2:

$$CV_m \% = \frac{0.0442}{0.35} \times 100 = 12.63 \%$$

Graphical representation

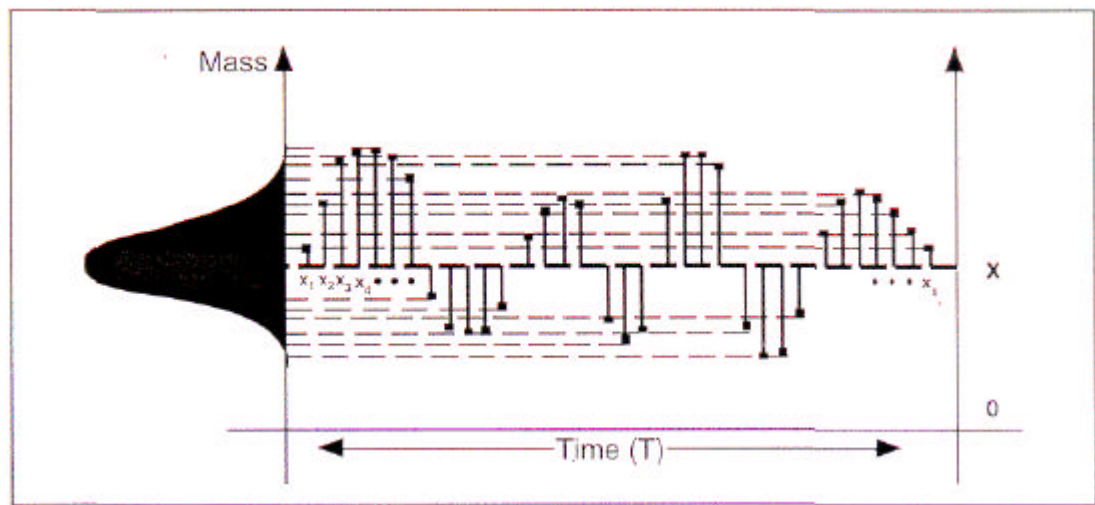


Figure 3.15. Graphical representation of mass variations [37]

These instantaneous mass values are denoted by $x_1, x_2, x_3, \dots, x_n$. The average mass $\bar{x}$ is given by;

$$\bar{x} = \frac{x_1 + x_2 + x_3 + \dots + x_n}{n} \dots \dots \dots (3.8)$$

The mass variations can be considered to conform approximately to a normal distribution (as shown in Figure 3.15) when a homogeneous fiber composition is available. A measure of the size of these mass variations is the standard deviation, expressed as;

$$S = \sqrt{\frac{\sum (\bar{x} - x_n)^2}{n-1}} \dots \dots \dots (3.9)$$

The coefficient of variation CVm % is defined as the standard deviation expressed as a percentage of the mean.

$$CVm \% = \frac{s}{\bar{x}} \times 100 \dots \dots \dots (3.10)$$

3.3.3.3. Relationship between irregularity $U_m\%$ and coefficient of variation $CV_m\%$

It can be considered that if the fiber assembly required to be tested is normally distributed with respect to its mass variation, a conversion possibility is available between the two types of calculation according to the following:

$$\frac{CV_m}{U_m} = \sqrt{\frac{\delta}{2}} = 1.25 \quad \text{Or:} \quad CV_m = 1.25 \times U_m \quad \dots\dots\dots (3.11)$$

Where an ideal normal distribution of the fiber assembly cannot be assumed, this conversion factor will be subject to error. In the following, certain cases are represented which occur quite frequently in the textile industry and with which the conversion factor referred to above cannot always be used.

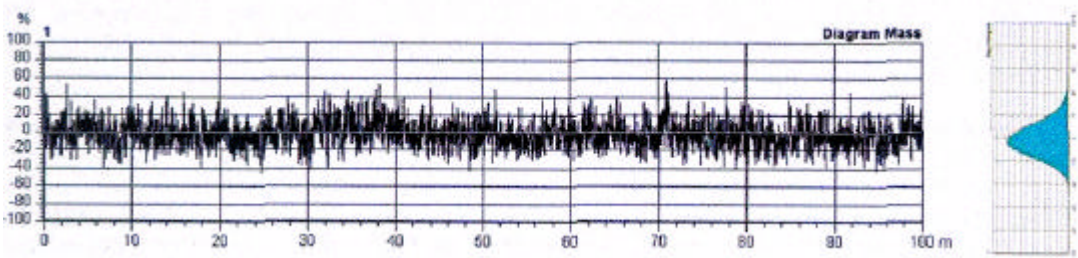


Figure 3.16. Diagram with normal distribution [38]

If the mass variation is distributed symmetrically, is single peaked and tends towards normal distribution, the conversion factor 1.25 can be used. This mass variation can be expected with fault-free fiber assemblies (Figure 3.16).

$$CV_m = 1.25 \times U_m \quad \dots\dots\dots (3.11)$$

If the mass variation is distributed asymmetrically and with a single peak (assemblies with frequent and accentuated thick places, Figure 3.17) the following conversion must be used:

$$CV_m > 1.25 \times U_m \quad \dots\dots\dots (3.12)$$

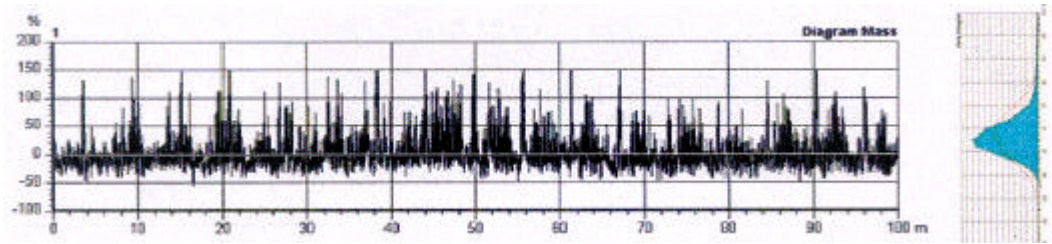


Figure 3.17. Diagram with asymmetrical distribution [38]

If strong periodic mass variations are available (double peaks, Figure 3.18) in a fiber assembly, the following calculation factor must be used:

$$CV_m < 1.25 \times U_m \dots\dots\dots (3.13)$$

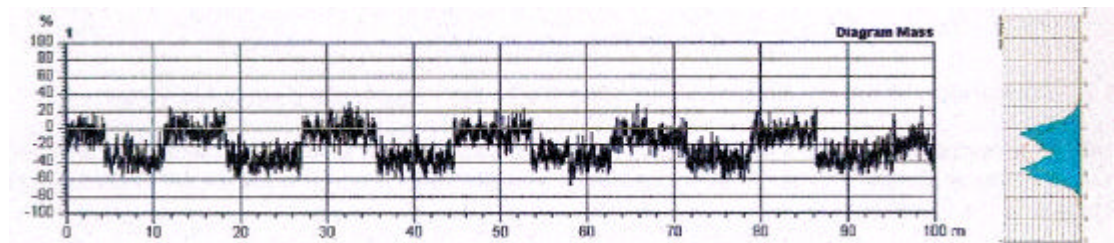


Figure 3.18. Diagram with long mass jumps [38]

The CV_m/U_m ratios in each of the above graphs are just for general use, and serve as examples. With normal staple-spun yarn for woven or knitted fabrics, it is unlikely that such large deviations would occur, therefore, the factor 1.25 is a good approximation [38].

3.3.3.4. Imperfections

Yarns spun from staple fibers contain "imperfections" which can be subdivided into three groups:

- a) Thin places.
- b) Thick places.
- c) Neps.

The reasons for these different types of fault are to be found either in the raw material or with an imperfect processing procedure. A reliable analysis of these "imperfections", therefore, will not only make possible the achievement of optimum conditions during the various manufacturing processes, but can provide some reference to the quality of the raw material used.

Thick places and thin places, referring to those, which can be classified under the term "imperfections", exceed -30% or +35% with respect to the mean value of yarn cross-sectional size. The type of "imperfection" will be defined with respect to their fault size (Figure 3.19) [38].

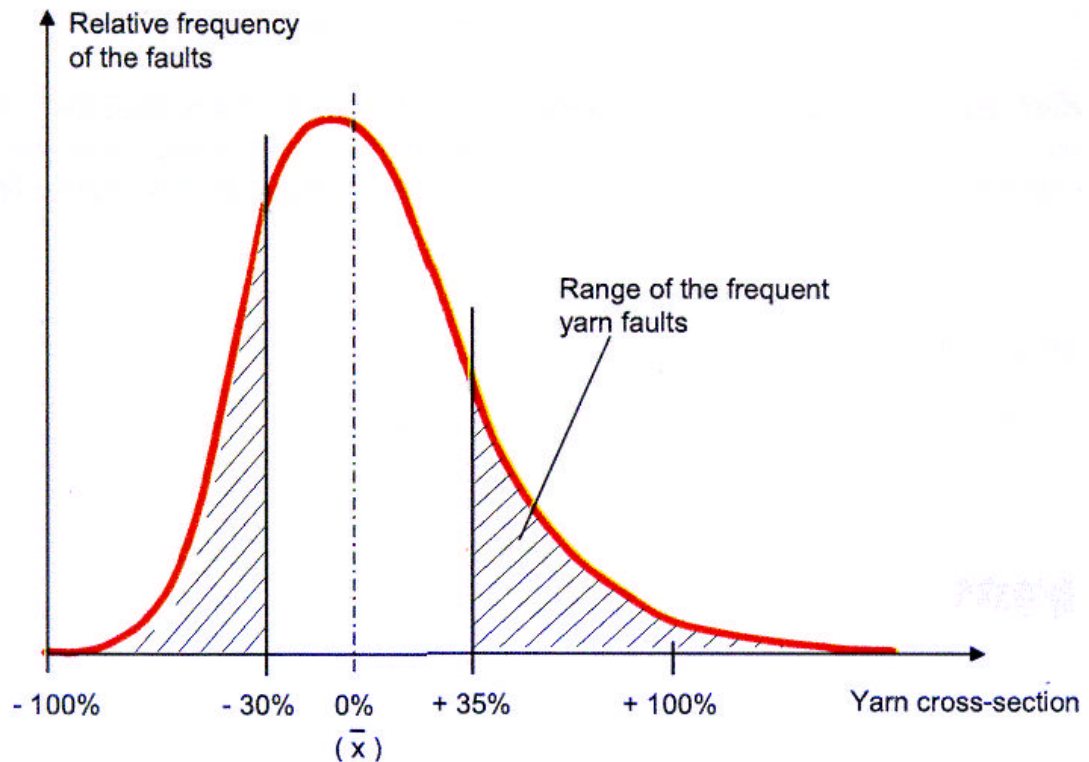


Figure 3.19. Distribution of imperfections [38]

Imperfections have a size of within $\pm 100\%$ as mentioned earlier. Faults are also present in the yarn with a size of above +100% or less than 100% but with a much longer length. They are relatively less frequent when compared to the imperfections and hence are called 'infrequent yarn faults' or 'seldom-occurring yarn faults' [36].

An evenness tester cannot normally give complete picture of the infrequent faults and they should be estimated using a separate instrument.

Thin places

Evenness testers allow the following sensitivity thresholds for thin places: -30% / -40% / -50% / -60%. Every time the selected limit is exceeded, a thin place is counted [38]. A yarn showing mass variations is given in Figure 3.20.

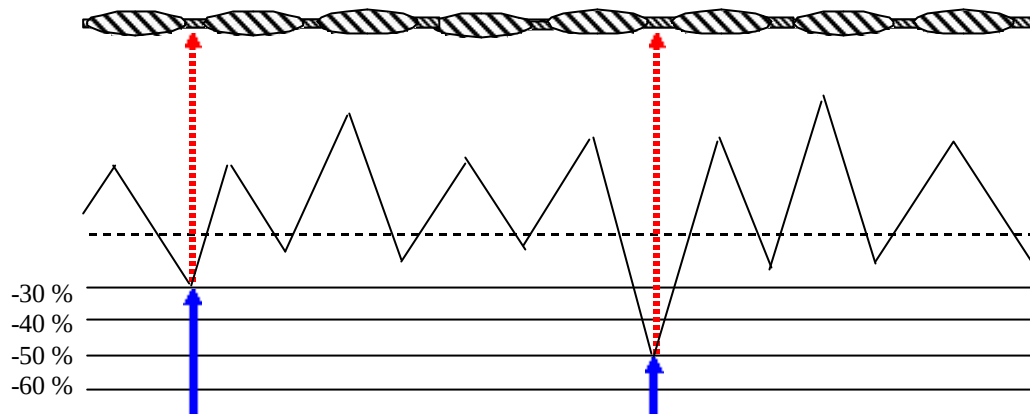


Figure 3.20. Mass variations showing thin places

In the above figure, it could be seen that the curve oversteps the sensitivity level of -50% at one place and the sensitivity level of -40% at one place. Also any thin place overstepping a lower sensitivity level will also be overstepping the higher sensitivity levels. Therefore, when this yarn is tested in an evenness tester, the imperfection indicator would record the number of thin places as 1 at a sensitivity level of -50% and 2 at a sensitivity level of -40% [36].

Thick places

Evenness testers the following sensitivity thresholds for thick places: +35% / +50% / +70% / +100%. Every time the selected limit is exceeded, a thick place is counted. Figure 3.21 shows a thick place in yarn and the corresponding yarn signal.

As thick places and neps must be counted separately, a differentiation has to be made between the two types of faults. Frequently-occurring thick places exhibit a length that corresponds with the mean staple length of the fiber. Therefore, the test equipment must be programmed so that it can differentiate between short staple yarns (cotton and cotton/polyester blends) and long-staple yarns (wool and wool/acrylic blends) on the spinning systems.

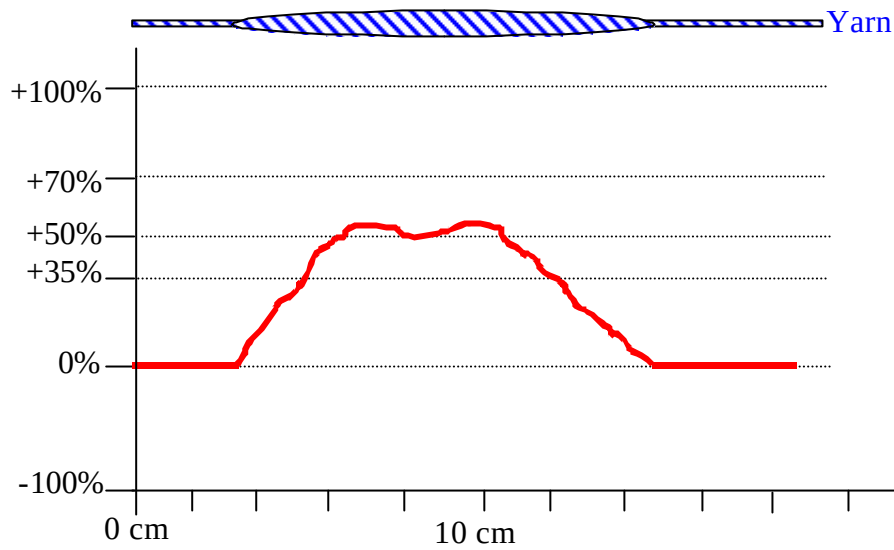


Figure 3.21. A thick place in a yarn and the corresponding yarn signal

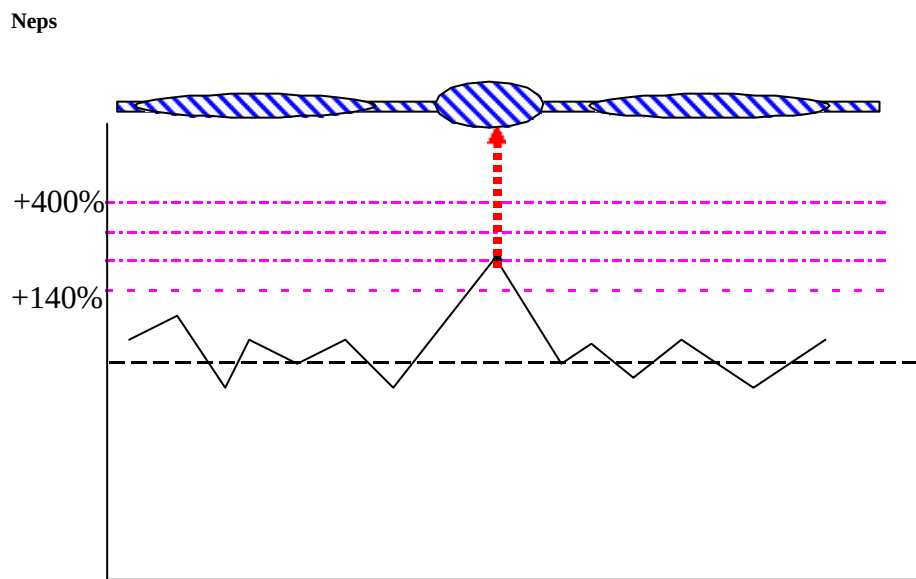


Figure 3.22. Mass variations showing neps

A nep is a thick place not exceeding a length of 4 mm. The mass increase is measured over a reference length of 1 mm and this increase, if oversteps the selected sensitivity level, then a nep will be registered (Figure 3.22) [36].

Neps can be divided, fundamentally, into two categories; raw material neps and processing neps. The raw material neps in cotton yarn are primarily the result of vegetable matter and immature fibers in the raw material. The influence of the raw material with wool and synthetic fibers in terms of nep production is negligible.

Processing neps are produced at ginning and also in cotton, woolen and worsted carding. Their fabrication is influenced by the type of card clothing, the setting of the card flats, workers and strippers, and by the production speeds use [23].

Importance of thin places and thick places

Thin places and thick places in a yarn can, on the one hand, quite considerably affect the appearance of a woven or knitted fabric. On the other hand, it cannot be concluded from an increased number of thin place faults that with this yarn, the downtime of weaving or knitting machines will be increased to a similar degree. Thin places usually exhibit a higher yarn twist (because of fewer fibers in the cross-section resulting in less resistance to torsion). The yarn tension does not become smaller proportionally with a reduced number of fibers.

With thick place faults the contrary is the case. More fibers in the cross-section result in a higher resistance to torsion. Thick places have therefore, in many cases, a yarn twist which is lower than the average. The yarn tension in the yarn at the position of the thick place is only in very few cases proportional to the number of fibers. These considerations are valid primarily for ring-spun yarns. The thick and thin places determined by evenness tester have a length approximately equal to that of the fiber in the yarn material (Figure 3.23).

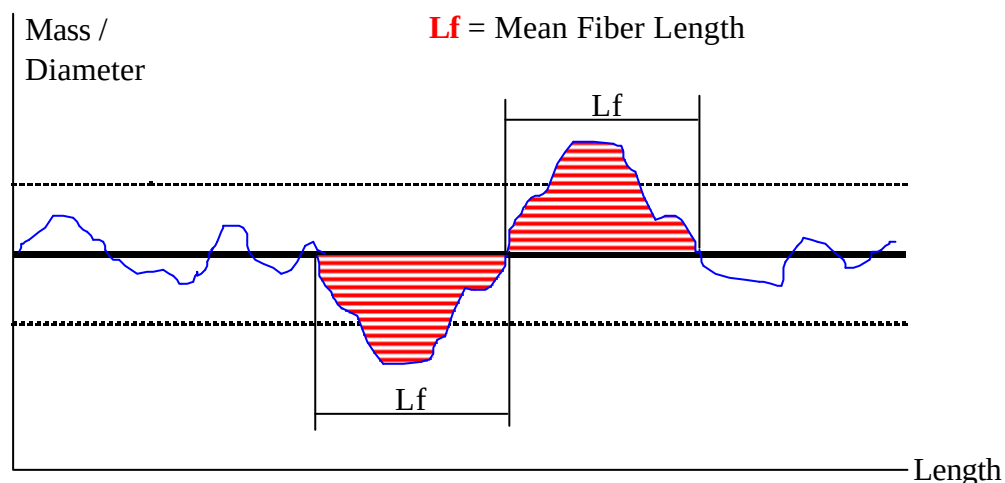


Figure 3.23. Mass variations showing a thin place and a thick place

Thick places and thin places which overstep the minimum actuating sensitivity of +35% and -30%, respectively, correspond in their length to approximately the mean

fiber length. Medium length or long thick and thin places are to be considered as mean value variations and are not counted by the instrument [38].

Importance of neps

Neps can influence the appearance of woven or knitted fabrics quite considerably. Furthermore, neps of a certain size can lead to processing difficulties, particularly in the knitting machine sector of the industry. Consequently, the avoidance of neps in the production of spun yarns is a fundamental textile technological problem.

The choice of the setting 'short staple' and long staple'

Evenness testers offer a choice of selection of either 'short staple' or 'long staple' as the setting for measurement of imperfections.

With a 'short staple' setting, the reference length taken into consideration for measurement of thick places is 30 mm and with a 'long staple' setting, the corresponding reference length is 60 mm. These two settings are provided to enable accurate measurement of thick places, since the length of a thick place has been found to be proportional to the fiber length. Accordingly, the correct choice of this setting should be made taking the mean fiber length as the reference point. As a general guideline, yarns whose mean fiber length is up to 40 mm are tested with a 'short staple' setting and yarns with mean fiber length of above 40 mm are tested with a 'long staple' setting.

If the mean fiber length values are not readily available, it can be indirectly obtained from the maximum wavelength of the spectrogram.

$$\text{Mean Fiber Length} = \lambda_{\text{max}} / 2.82 \dots\dots\dots (3.14)$$

Yarns with mean fiber length shorter than 40 mm are recommended to be tested with a 'short staple' setting.

At a mean fiber length of 40 mm,

$$\lambda_{\text{max}} = 2.82 \times 40 \text{ mm} = 11 \text{ cm}$$

Therefore, if the maximum of the spectrogram lies at or to the left of this limiting wavelength i.e. 11 cm, then one must measure with 'short staple' setting and if the maximum occurs to the right of 11 cm, then one must measure with the setting 'long staple'.

What happens when these guidelines are not followed? The significance of any mass deviation will be reduced if the reference length for measurement of such deviation is widened. As a consequence, a yarn when measured with a 'long staple' setting for imperfections will show less thick places relative to a measurement with 'short staple' setting. Therefore, if the recommendations with respect to the choice of this setting are not followed, the thick place values are likely to be either low or high [36].

The following table 3.3 summarizes the recommended setting as well as the effect of an incorrect setting.

Table 3.3. Effects of staple length choice on the number of thin and thick places

Mean Fiber Length	Recommended Setting	Incorrect Actual Setting	Effect
$\leq 40 \text{ mm}$	Short staple	Long staple	Less thick places
$> 40 \text{ mm}$	Long staple	Short staple	More thick places

3.3.4. Graphical representation of mass variations

Graphical representations are aimed at providing easy analysis possibilities as well as providing more complete information than the numerical estimates. With graphical representations, long term trends of changes in mean value, sporadic deviations, periodicities in faults etc., can be easily identified. Also elaborate statistical calculations are generally not required for interpreting graphical representations [36].

The following graphical representations are common with the latest generation evenness testers.

- a) Spectrogram.
- b) 3D spectrogram.
- c) Variance Length Curve.
- d) 3D Variance Length Curve.

- e) Normal Diagram.
- f) Cut Length Diagram.
- g) Histogram.

3.3.4.1. Spectrogram

Periodic mass variations in the yarn result in disturbing patterns in woven and knitted fabric. They are never caused by the raw material, but are due to faults in processing. Such faults have to be detected as early as possible. The spectrogram serves for the analysis of periodic defects.

Periodic defects are, however, extremely frequent not only in the products prior to spinning, but also in yarns, because defective card clothing, out-of-center running rollers in draw-boxes, defective aprons, etc., can all produce periodic mass variations. It is unfortunately not possible in most cases that one can recognize and analyze this type of fault from the diagram. For this purpose, the spectrogram is available.

The spectrogram is a representation of the mass variation in the frequency domain, whereas the diagram is a representation in the time domain (Figure 3.24, Figure 3.25).

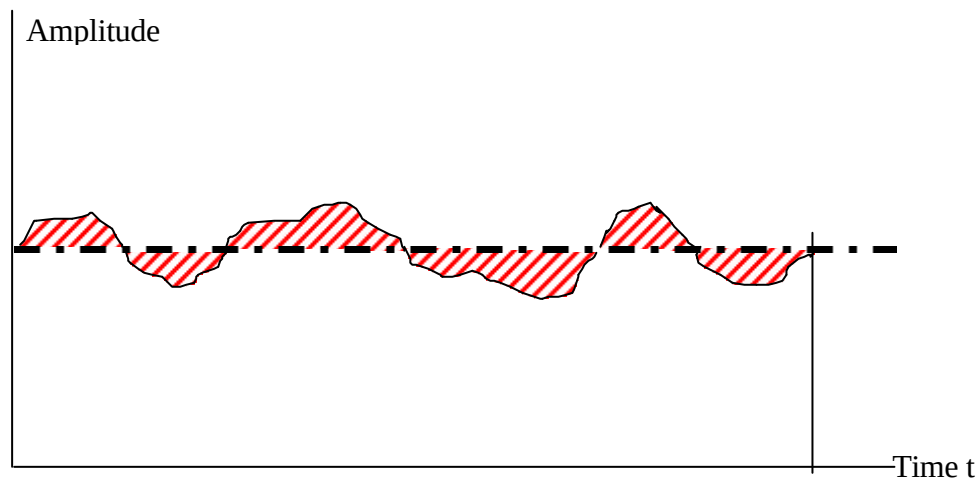


Figure 3.24. Diagram: Representation of the mass variations in the time domain

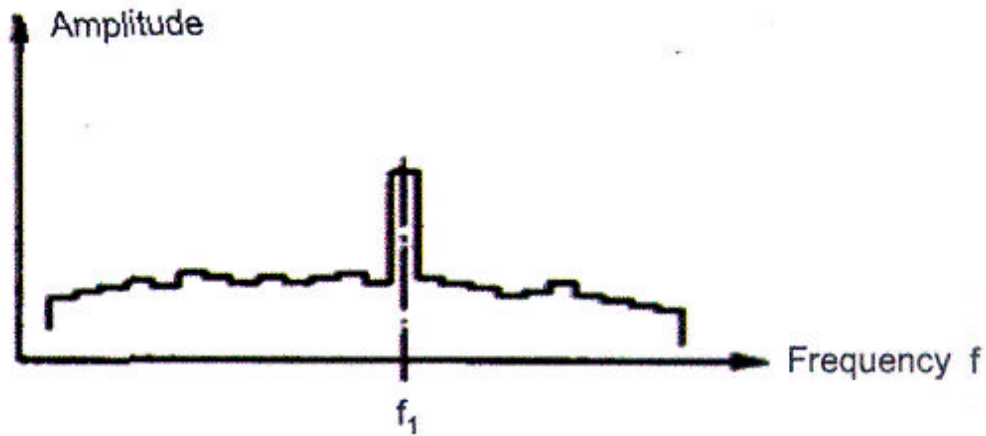


Figure 3.25. Representation of mass variations in the frequency domain [36]

If, therefore, a periodic fault occurs in the fiber material with the frequency f_1 (Figure 3.25), this leads to a peak in the spectrogram at the position f_1 . For textile trials, however, the frequency spectrum is not very practical. One prefers, for such trials, a representation which makes reference to the wavelength. Between frequency and wave-length there is a simple relationship:

$$f = \frac{v}{\lambda} \dots\dots\dots (3.15)$$

f = frequency (s^{-1})

λ = wavelength (m)

v = material speed (m/s)

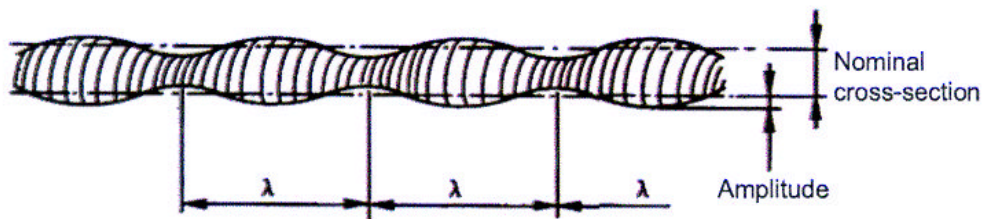


Figure 3.26. Periodic faults in a fiber assembly [38]

The wave-length indicates directly at what interval the periodic faults repeat (Figure 3.26). The exact designation for the curve is the wave-length spectrum (Figure 3.27).

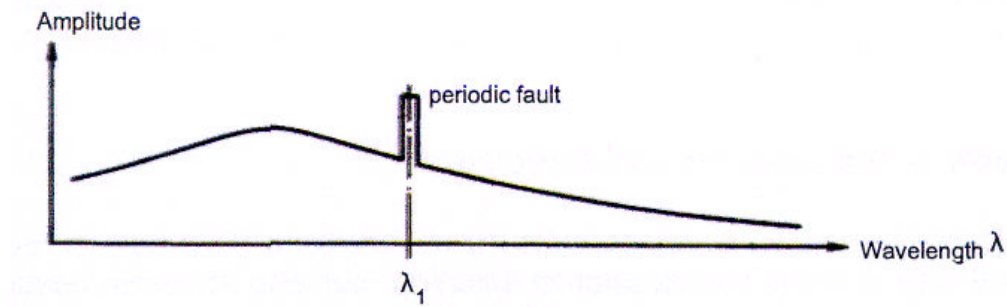


Figure 3.27. Spectrogram with periodic fault [38]

Advantages of the spectrogram with respect to the diagram:

- a) In the diagram, various types of periodic faults can also be recognized, but the proof of these is much more difficult without the spectrogram.
- b) Two or more periodic faults in the same fiber assembly can hardly be recognized in the diagram, whereas they are clearly evident in the spectrogram.
- c) The proof of periodic faults in the diagram requires, in many cases, a drastic reduction of the testing speed, whereas the spectrogram can be traced out with the highest testing speed [38].

Chimney type faults

If a periodic mass variation with the wave-length λ appears in the fiber material, a peak is recorded in the spectrogram at the position λ . The height of this peak is a measure of the intensity of the periodic fault. In this case, the wavelength λ is 20 m (Figure 3.28, Figure 3.29).

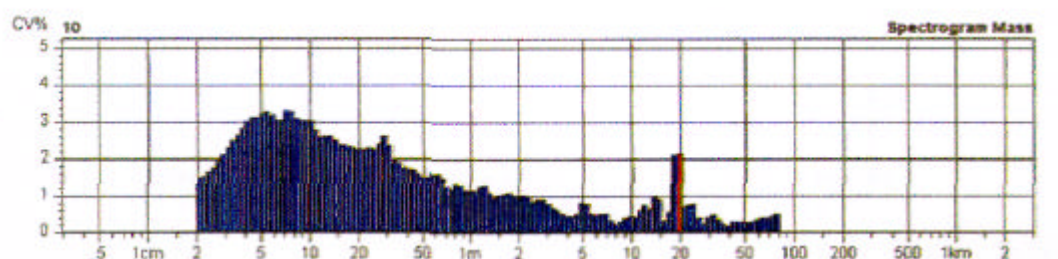


Figure 3.28. Spectrogram with a 20 m chimney fault [38]

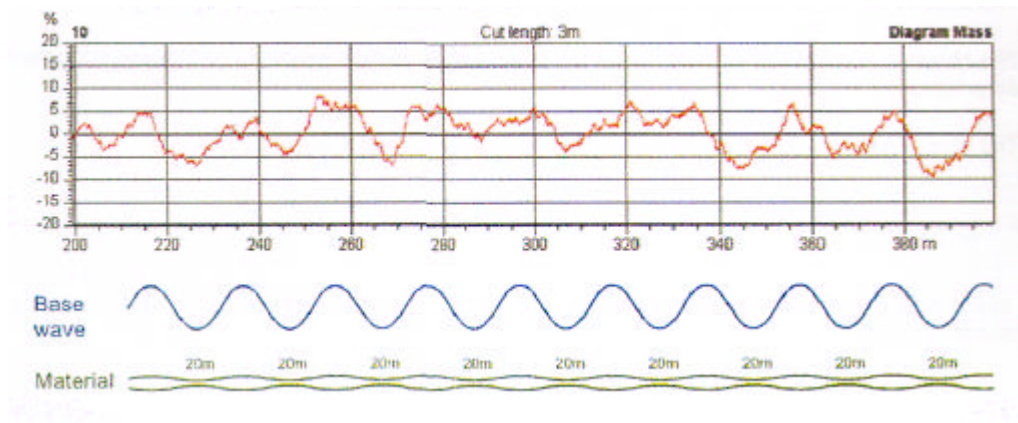


Figure 3.29. Cut-length mass diagram of the same material as in the top spectrogram, showing the 20 m periodic mass variation [38]

The ideal base wave (sine wave) of the periodicity and an amplified illustration of how the test material's corresponding mass variation would look are drawn alongside the diagram.

The spectrogram is used to check the test material for any abnormally high periodic or systematic mass variations. In most cases, those variations are due to dirty or defective cylinders or wrongly set preparation and spinning machinery [38].

Hill type faults

Unlike a true periodic defect, a drafting wave repeats over a range of several wavelengths. Because of its nearly periodic nature, a drafting wave appears as several wavelengths. A fault of this type leads to an increase in the spectrogram at the corresponding wave-length range and not to a distinct peak.

Drafting waves can cause very serious thick and thin places that result in poor yarn performance and unacceptable fabric appearance.

To this group of nearly periodic faults belongs, for instance in the staple section, not perfectly set drafting elements (swimming fibers), and in the range of synthetic filament yarns, the nearly periodic vibration of the filaments in the quench air duct (as a result of the cooling air). A spectrogram of this fault group is shown in Figure 3.30. With staple fibers drafting waves are mostly known in cotton, as the short fibers can only be guided inadequately in the

draw box. Drafting waves do not cause distinctive patterns in the end product, as shown for the periodic faults, but produce more a "cloudy" appearance [38].

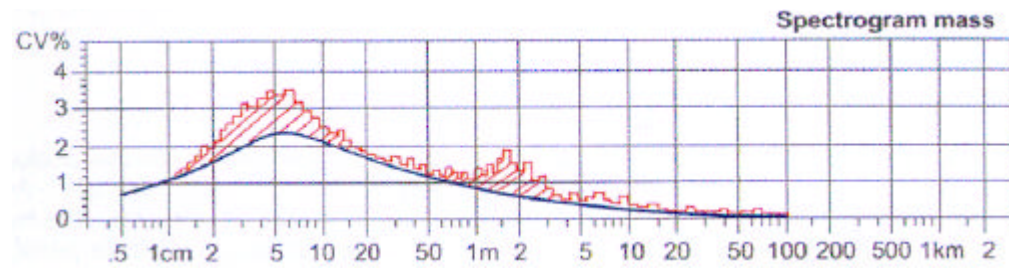


Figure 3.30. Spectrogram with hill type faults [38]

Numerous measurements of staple-fiber materials have shown that there are rules for the correlation between the appearance of drafting waves in the spectrogram and the mean staple length. It is given below;

- a) yarn : 2,8x fiber length
- b) roving : 3,2 x fiber length
- c) combed sliver : 3,5 x fiber length
- d) draw frame sliver : 3,5x fiber length

Lengthening of periodic mass variations via drafting

A periodic fault which occurs at some stage or another in the spinning process is lengthened by subsequent drafting. If, for instance, the front roller of the second draw frame has a certain eccentricity as shown in Figure 3.31, then, knowing the various drafts, the position of the peak in the spectrogram with a yarn measurement can be calculated.

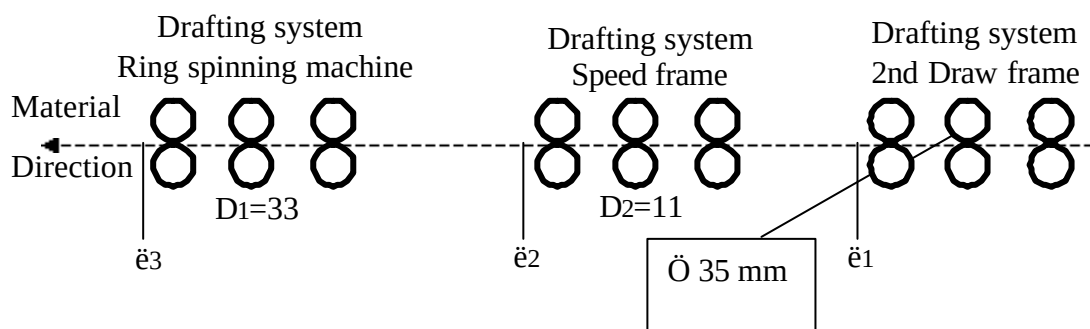


Figure 3.31. Drafting systems of spinning machines

The eccentricity of the draw frame roller results, at the output of the second draw frame, in a periodic fault λ_1 of $3.5 \times \pi = 11$ cm.

At the output of the speed frame drafting elements, at the roving bobbin, the wave-length of this fault λ_2 will be $11 \times D_2 = 11 \times 11 = 121$ cm.

In order to calculate the wave-length of the yarn, this value is to be multiplied by the draft at the ring spinning machine. In the yarn, therefore, this periodic fault will have a wave-length of $\lambda_3 = \lambda_2 \times D_1 = 121 \times 33 = 4000$ cm = 40 m

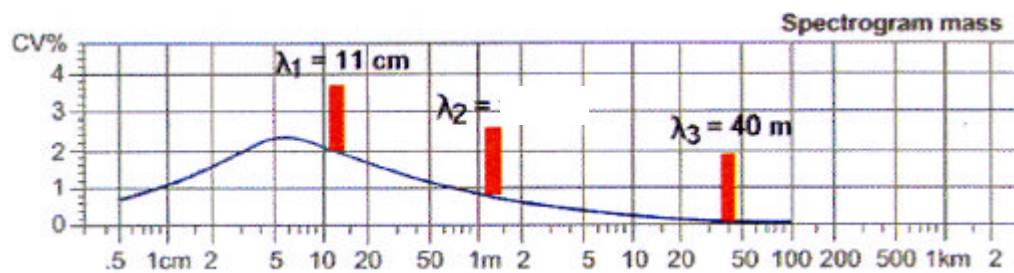


Figure 3.32. Spectrogram with chimney type faults [38]

Figure 3.32 shows the position of the peaks of λ_1 , λ_2 , and λ_3 in the spectrogram. The reason was an eccentric front roller at the second draw frame. In the yarn, therefore, due to the drafts at the speed frame and ring spinning machine, a periodic fault with a wavelength of $\lambda_3 = 40$ m is produced [38].

3.3.4.2. Variance length curve

The coefficients of variation at different cut lengths provided by the evenness testers provide invaluable information with regard to the variations prevalent at the specific cut lengths. Therefore independently, the short, medium, and long term variations could be studied by estimating the coefficient of variation of the required cut length. However, such numerical values cannot directly provide complete information on the source of faults. The spectrogram provides a possibility of localizing the source of fault but with a spectrogram, only faults of periodic nature could be identified and that too, in most cases, only if proceeded by some other means of identifying the machine / processing stage responsible for the fault [36].

Variance length curve is a graphical representation of the coefficient of variation (CV %) against the reference cut length. The representation is explained with a simple hypothetical example (Figure 3.33).

Consider a longitudinal strand of fibers cut up into several equal segments of length l_1 . For purposes of explanation let us further assume that the length of the segment corresponds to the measuring field length of the evenness tester.

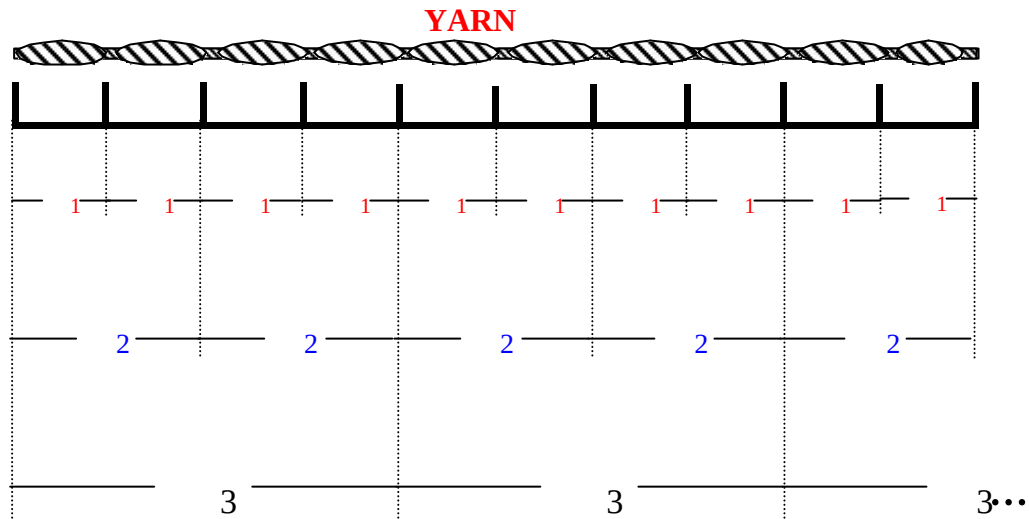


Figure 3.33. Representation of different cut lengths

Ideally, for obtaining mass variations at different cut lengths, the measuring field length should be increased. For construction reasons, it is not possible to physically lengthen the measuring field of the evenness tester beyond a certain length. Therefore, the extension of the measuring field has to be simulated by the instrument according to electronic means.

For constructing the variance length curve, the measuring field length is taken as the basic cut length at which the CV is calculated and plotted. For variations at other cut lengths, the mass of successive portion of material are added up and the CV calculated. Accordingly the variations of mass at cut length l_2 are estimated by summing up the mass values of two successive portions of material with length l_1 and calculating the coefficient of variation. Similarly CV of mass at cut length l_3 would be estimated by summing up the mass values of 4 successive l_1 lengths of material or 2 successive l_2 lengths of material and calculating the CV. When all

these CV values are plotted against their respective cut lengths, we get the variance length curve as in Figure 3.34 [36].

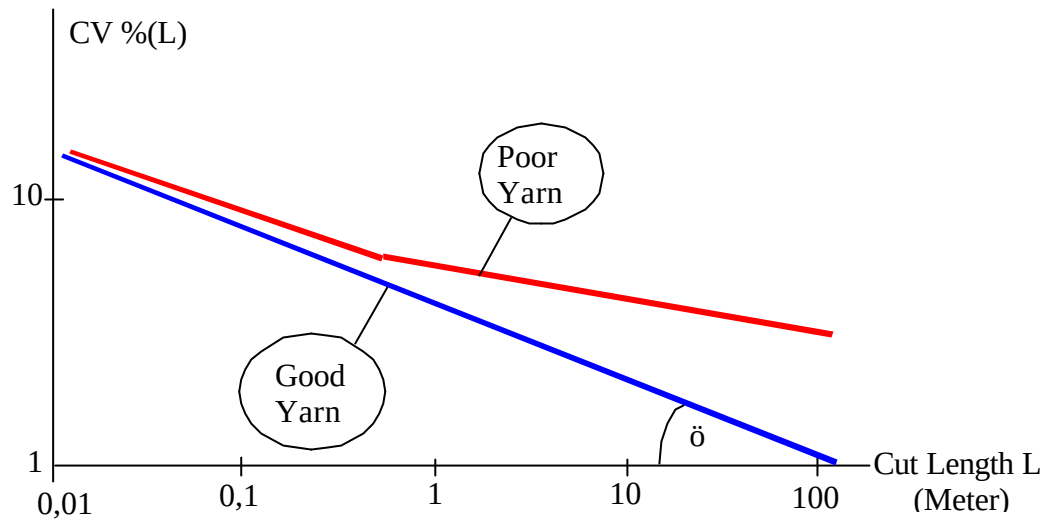


Figure 3.34. Variance length curve

The variance length curve for the same raw material and same ideal processing conditions will always be a straight line with an unchanged angle ϕ of inclination. Deviations from the straight lines must therefore indicate problems caused by the machine or the raw material [38].

The variance length curve with increasing cut length L continuously decreases can be explained with reference to Figure 3.35.

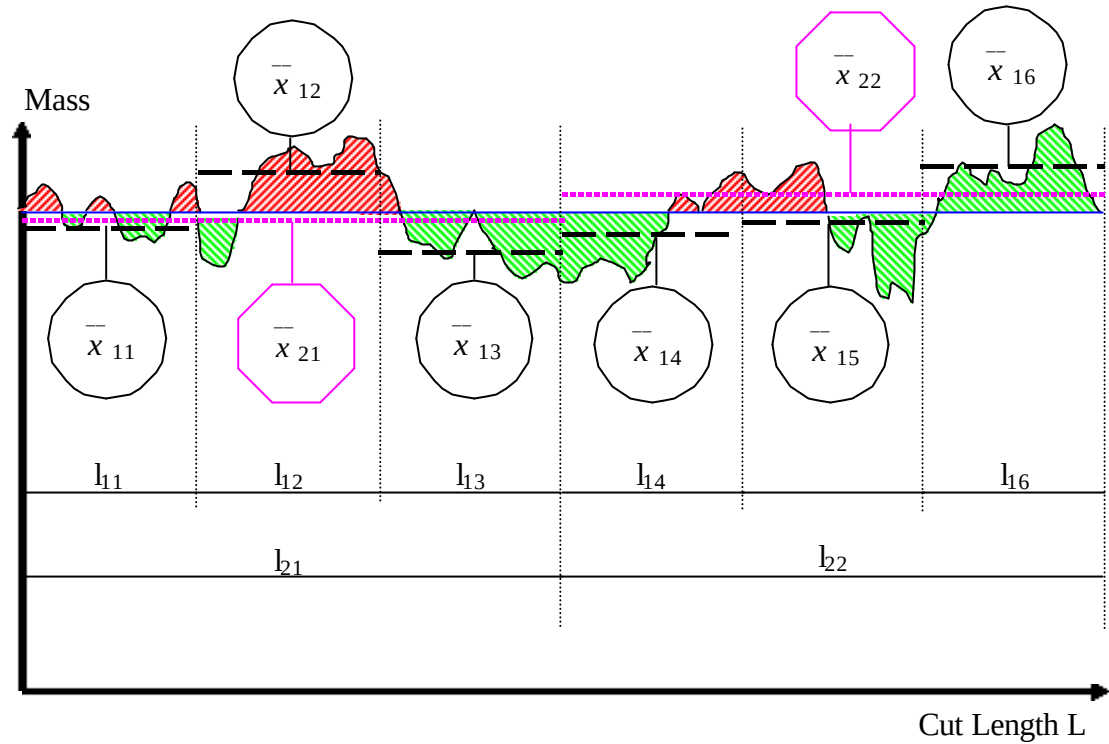


Figure 3.35. Mass diagram

If the fiber assembly is cut up into short pieces of length $l_1 \dots l_6$, the mean values $\bar{x}_{11}, \bar{x}_{12} \dots \bar{x}_{16}$ will vary much more intensively than if the fiber assembly was cut up into longer pieces b_1 and b_2 . Figure 3.35 shows that the differences between the two mean values $\bar{x}_{21}$ and $\bar{x}_{22}$ are only small. The longer the cut length, therefore, the more the short-term variations will compensate each other, and the difference with respect to the mean value from piece to piece will be dependent only on the intensity of the long-term variations.

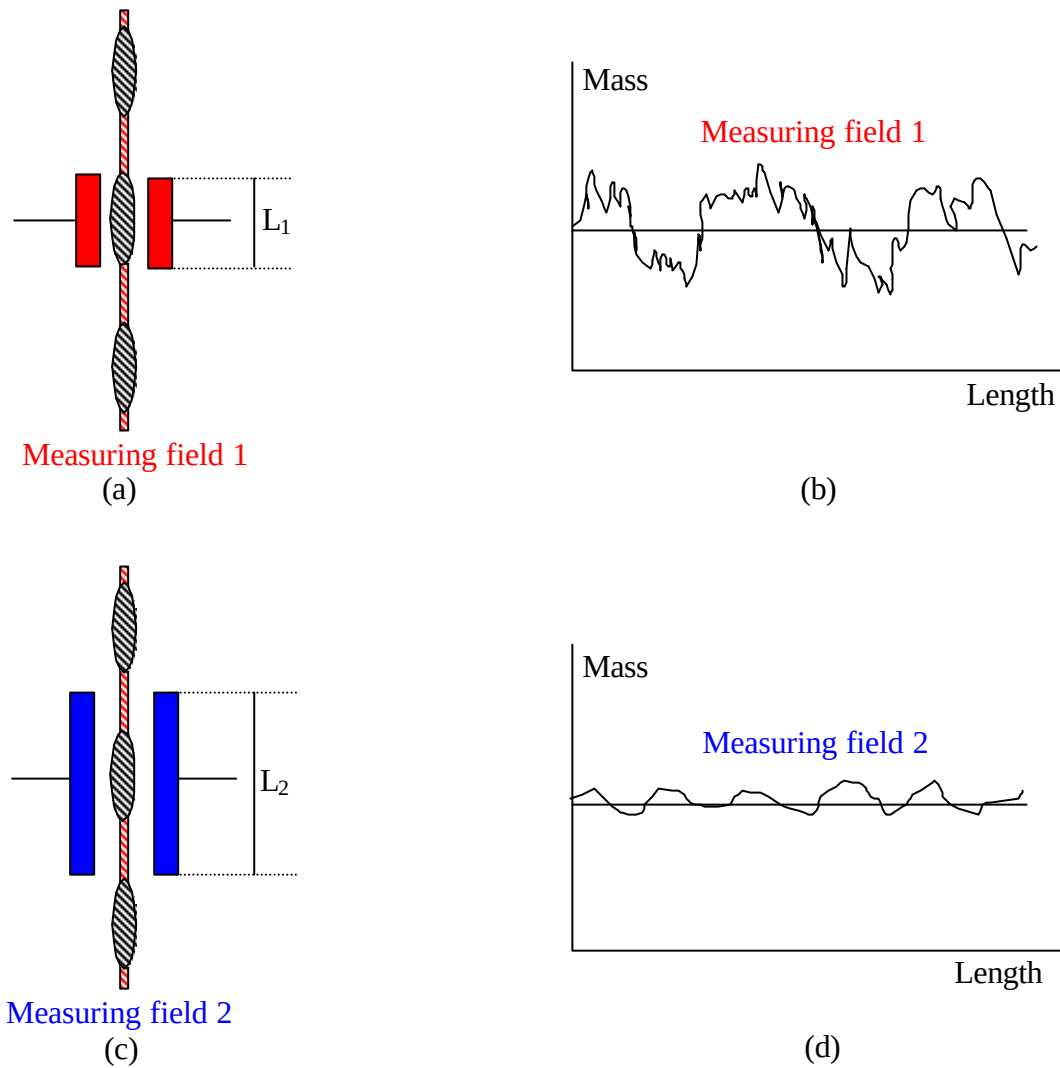
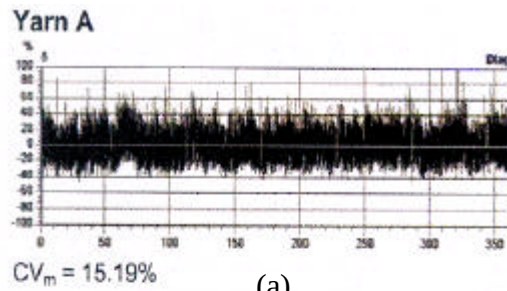


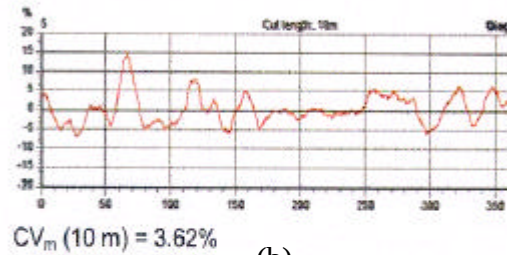
Figure 3.36. (a-d) Influence of measuring field lengths on the diagram

Figure 3.36 shows the influence of the measuring field lengths on the diagram. With an evenness tester, the measuring field has the length l_1 . Mass variations, in the fiber assembly, which are shorter than l_1 , cannot be truly represented. The extremely short-term variations will be averaged out. The measuring field length is accordingly proportional to the cut length. If now the measuring field is lengthened, then the "cut length" will also be increased (l_2). A fiber assembly in an extended measuring field is averaged out according to the longer length. The longer the measuring field, the less will be the influence of the short-term variations on the CV value [38]. Figure 3.37 shows application examples for diagrams with longer cut lengths.



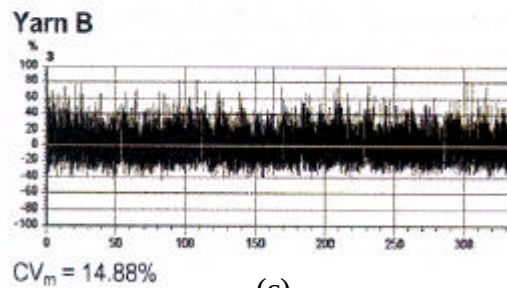
(a)

Diagram A at normal test length: It is difficult to recognize long-term variations.



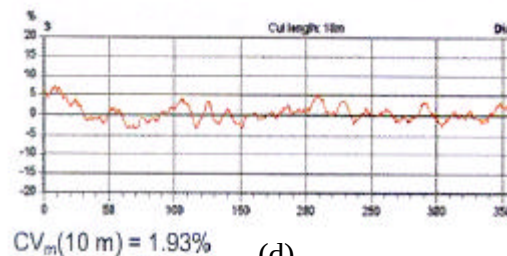
(b)

Same diagram with cut-length of 10m: It is easy to recognize long-term variations. Long-term variations are indicated by a high CV_m (10 m) of 3.62%. Diagram scale $\pm 20\%$.



(c)

Diagram B at normal test: As the short-term variations also dominate in this case it is hardly possible to recognize long-term variation.



(d)

Diagram B with cut-length of 10 m: This diagram only shows small long-term variations. The small long-term variations are indicated by a low CV_m (10 m) of 1.93 %. Diagram scale $\pm 20\%$.

Figure 3.37. (a-d) Application examples for diagrams with longer cut lengths [38]

3.3.4.3. Diagram

The diagram is an important part of evenness testing. It contains a large amount of information which cannot be provided by the spectrogram, by the U/CV value or by the counting of imperfections. The diagram is especially valuable for the detection of the following faults:

- a) Seldom-occurring events.
- b) Long-term variations.

- c) Periodic mass variations with wavelengths which are longer than 100 m and therefore cannot be confirmed by the spectrogram.
- d) Extreme thick and thin places.
- e) Randomly-occurring thick and thin places which tend to occur in batches.
- f) Slow changes of the mean value.
- g) With periodic faults, it can be determined whether the fault is permanently present or occurs only in batches.
- h) With measurements "within" a bobbin, seldom-occurring events can be found and changes in the mean value taking place over a number of kilometers can be confirmed.
- i) With unusual measured values the diagram can often be used to demonstrate whether these refer to a faulty or to a correct measurement [38].

Normal diagram

The mass diagram directly shows the mass variation of the test material in graphical form. A normal diagram contains the entire information from which the other test results (CV, Spectrogram, and Imperfections.) are derived.

The vertical axis shows the (+) and (-) mass deviations of the test material. The zero line along the middle represents the average value of the material. This average value is determined over the first meters of test material running through the sensor. The horizontal axis represents the length of the material (in meters or yards) which has been tested [38]. Figure 3.38 shows a normal diagram.

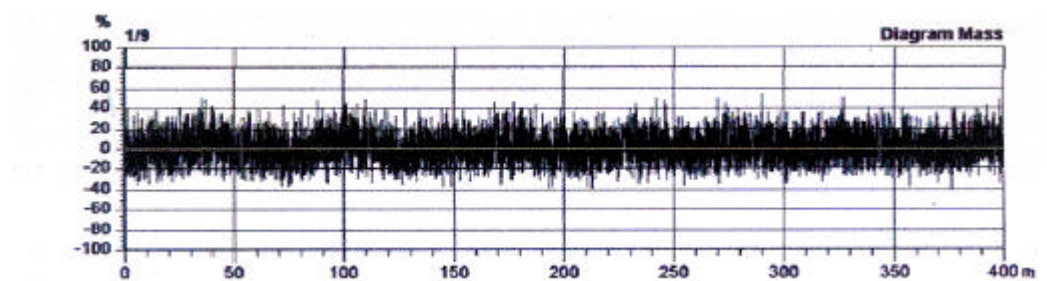


Figure 3.38. Normal diagram [38]

The mass diagram shows if there are any significant random mass deviations or increased variation along the tested material.

Cut length diagram

If the cut length for a diagram deviates from the normal cut length, the diagram will look different. The short deviations will disappear and the long-term deviations will become more apparent.

The following three diagrams (Figure 3.39, 3.40, and 3.41) were generated from the same yarn. The following cut lengths were chosen: 10 m, 1 m, and 0.01 m (normal).

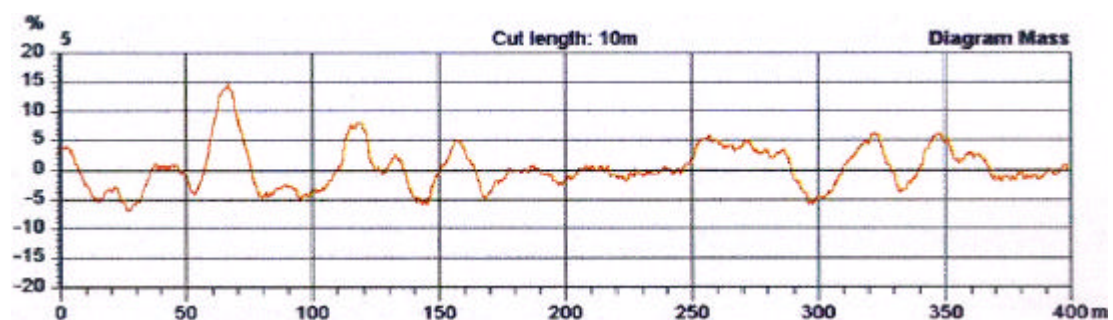


Figure 3.39. 10 m cut length diagram, scale 20 % [38]

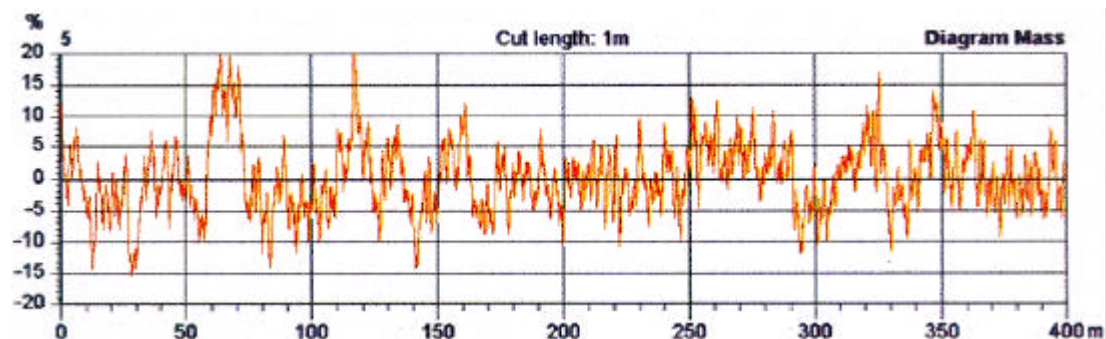


Figure 3.40. 1 m cut length diagram, scale 20 % [38]

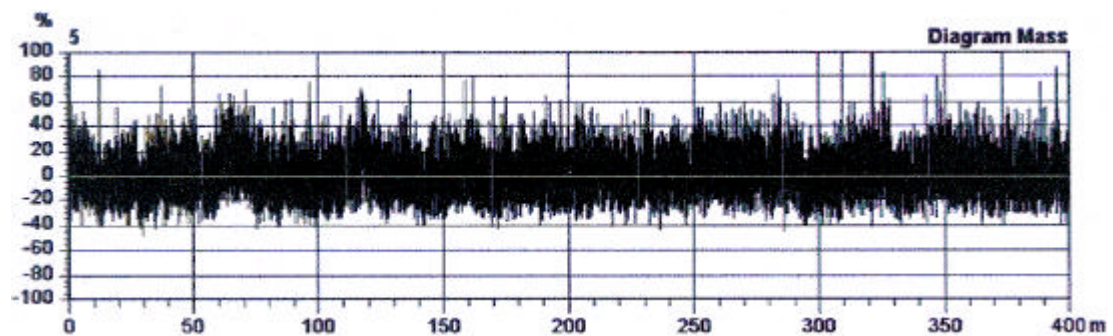


Figure 3.41. 1 cm cut length diagram (=Normal diagram), scale 100 % [38]

The principle of the diagram for longer cut lengths

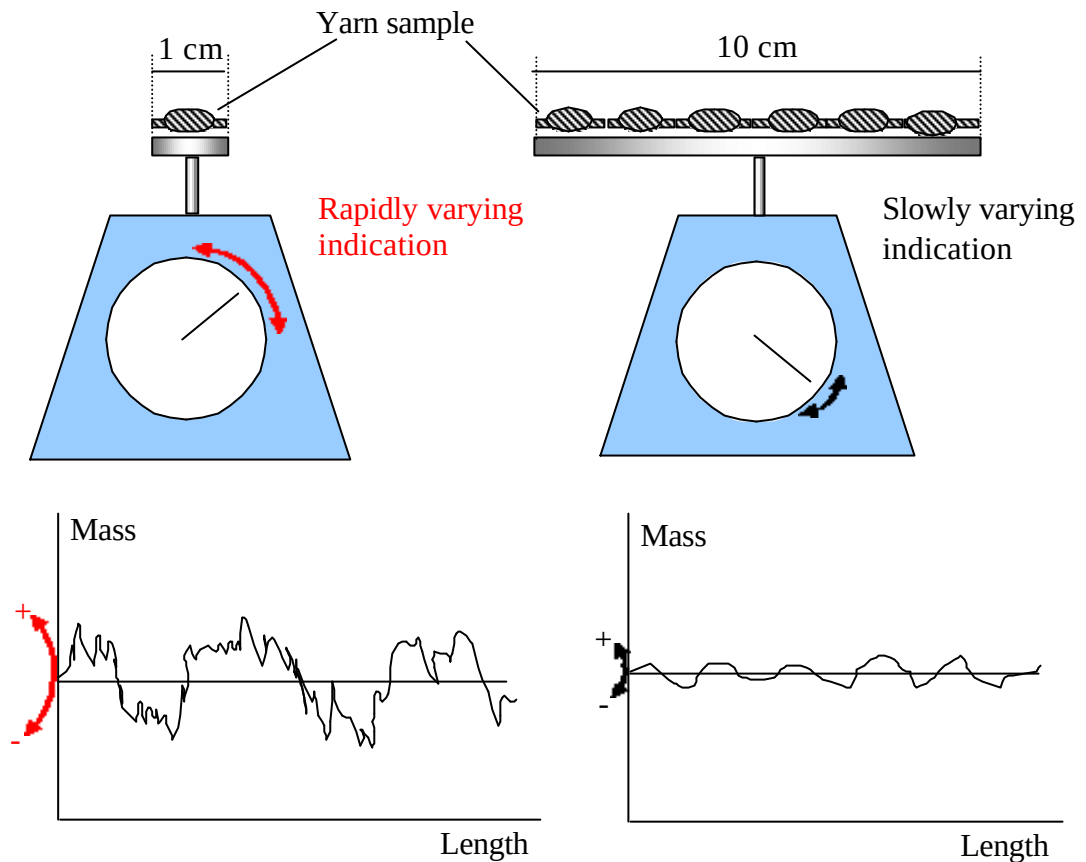


Figure 3.42. The measurement of yarn pieces of 1 cm cut length (left scale) and the measurement of yarn pieces of 10 cm length (right scale).

The measurement of yarn pieces of 1 cm cut length (left scale) results in higher mass variations than the measurement of yarn pieces of 10 cm length (right scale) (Figure 3.42).

A balance that is measuring short lengths of slivers, rovings or yarns would show more variations than a balance measuring longer pieces of test material or material passing through a measuring slot of 1 cm length would show much more variation than through a measuring slot of 10 cm length, where the shorter variations would be averaged out [38].

3.3.4.4. Histogram

In a histogram the data are presented as series of rectangles erected over the horizontal scale. The width of a rectangle is the class interval and its area represents the class frequency [5].

Histogram of mass variations is a distribution diagram of the mass variations. It shows in condensed graphical form information on all measured mass deviations over the whole test length (Figure 3.43).

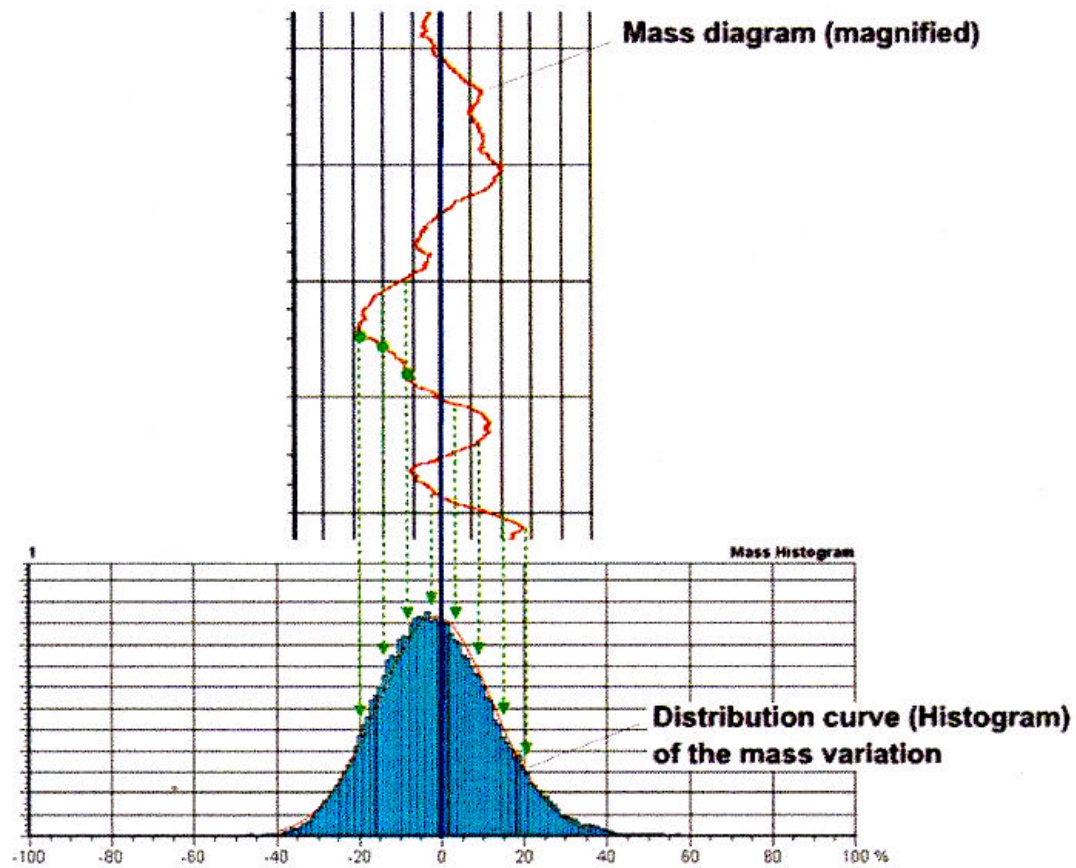


Figure 3.43. Relation between diagram and histogram [38]

Each individual scan point in the diagram represents one value in the histogram, at the same deviation relative to the average value 0% on the diagram.

Application of histogram

Mass deviations are approximately normally distributed. Deviations of the histograms compared to normal distribution indicate disturbances in the manufacturing process (asymmetrical distributions, two-peaked distributions). Especially in the production of filament yarns, histograms react very quickly to changes in the production process [38].

CHAPTER 4 SOFTWARE

4.1. Introduction

Software is a computer program or sets of instructions that tell a computer what to do. Software is distinguished from the actual hardware and it may act on the hardware that is attached to the computer. The computer itself, the hardware, could do nothing without the programs, the software that runs on it [39].

The main part of this study is the design of a software to analyze mass variation of ring spun yarns. The designed software was named as Yarn Quality. Delphi computer programming language was used to design “Yarn Quality” software. Delphi is an object oriented, component based, visual, rapid development environment for event driven Windows applications, based on the Pascal language. The user interface of Delphi application is based on forms, which hold all the components that needed to get and display information: buttons, menus, labels, edit boxes, list boxes. The code it generates runs very rapidly, and is very stable [40]. Because of these advantages, Delphi 6.0 computer programming language was used to design “Yarn Quality” software.

“Yarn Quality” software performs the numerical calculation of quality parameters of yarns such as: unevenness (U_m %), coefficient of variation (CV_m %) at different cut length, imperfections and the number of long thin - thick places. Also the software draws graphical quality parameters such as diagram, spectrogram, and histogram.

In this chapter usage of the software, calculation methods of numerical quality parameters, and drawing methods of graphical quality results were explained in details.

4.2. The Software

The main screen of the software is illustrated below and a sub screen of the software is given in Figure 4.2.

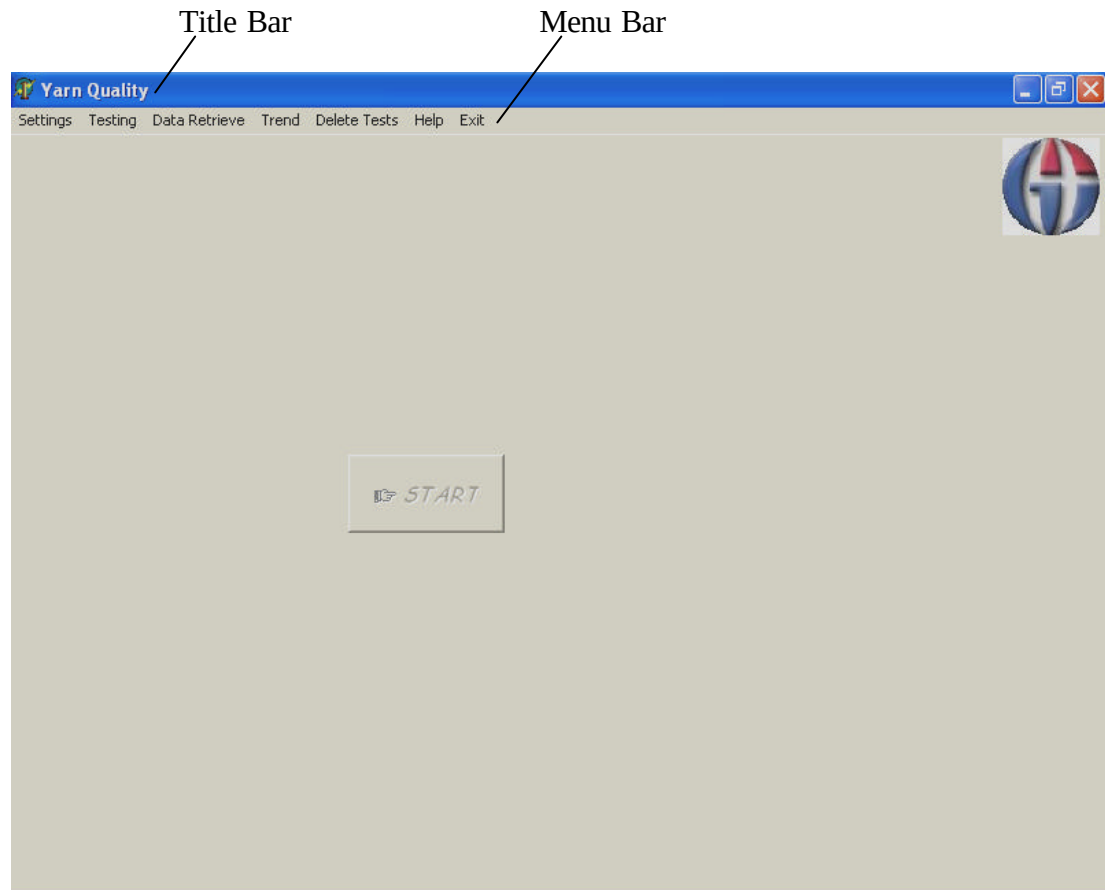


Figure 4.1. Main screen of software

Title Bar: The title bar is a horizontal bar located at the top of the screen. It gives the name of the application.

Menu Bar: The menu bar contains the main menu screen of software under which several submenus of the system are arranged. The submenus can be selected by clicking the menu item in the menu bar.

For keyboard access to the menu items and buttons, a shortcut key is defined with a under lined letter. Pressing 'Alt' key in combination with the underlined letter opens that particular menu.

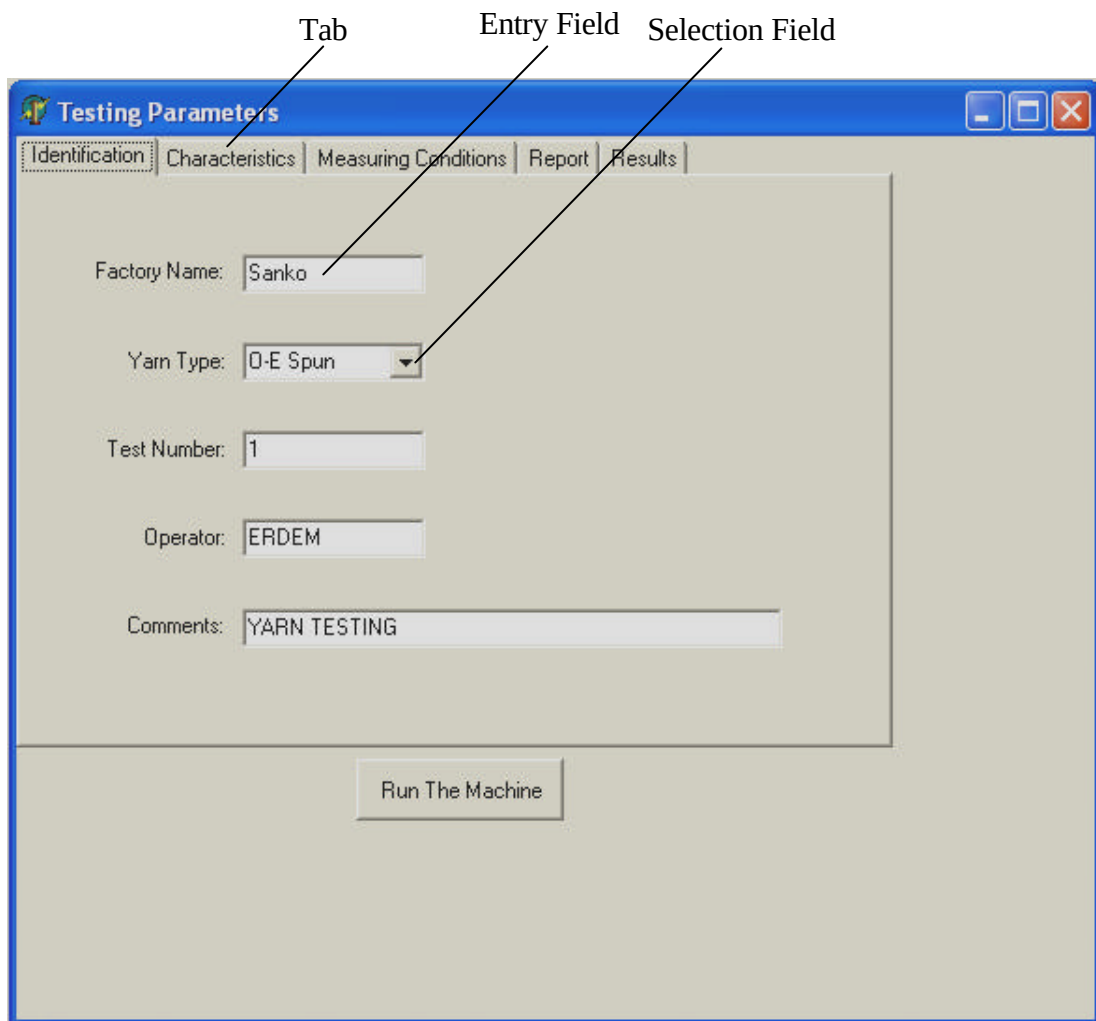


Figure 4.2. A sub screen of software

Tab: A particular screen can be opened by clicking on the tab title.

Entry Field: This field is for entering data, through the key-board. The entry can be made after clicking on the entry field.

Selection Field: This field contains a list of items which will be displayed if the pull- down button in the right corner of this field is clicked. The user can select any one item from the list by just clicking the item.

In Figure 4.3, block diagram of the menu arrangement is shown as a illustration list.

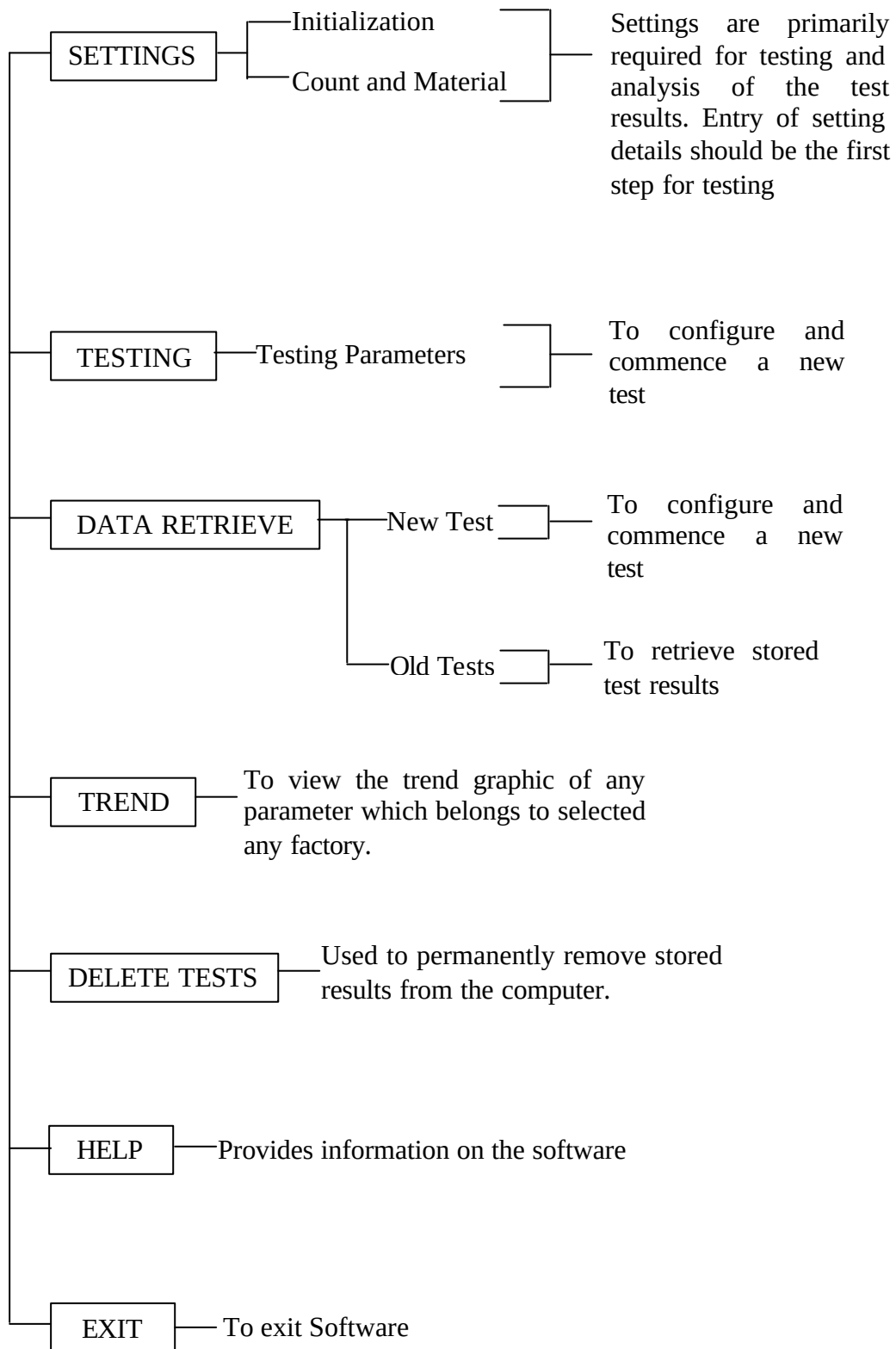


Figure 4.3. Block diagram of menu arrangement

4.2.1. Preliminary Settings

Primary setting details required for testing have to be entered prior to testing (Figure 4.4).

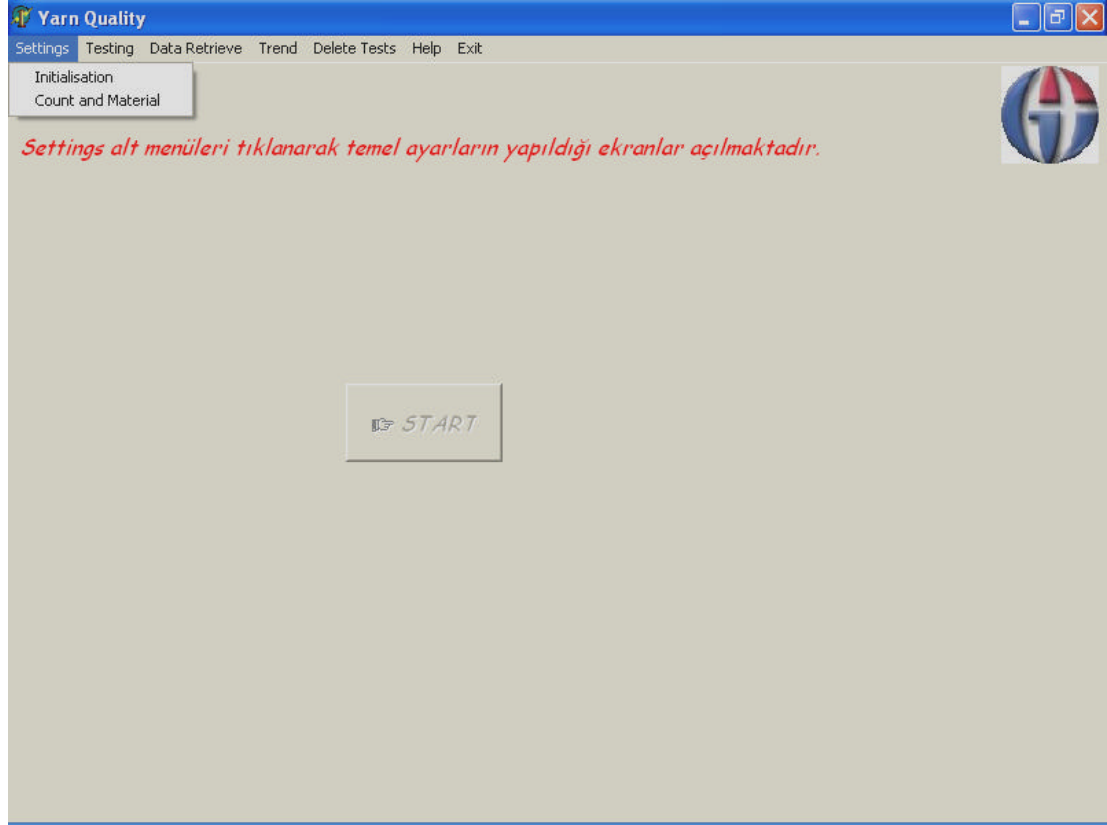


Figure 4.4. To view submenus of 'Setting'

4.2.1.1. Initialization

Initialization of the software requires input parameters based on which the internal measurement conditions will be calculatively modified to suite the material tested. Header details that appear in all test reports and measurement units in which the other preliminary settings will be made are to be set. The initialization screen is used to enter these important details (Figure 4.5).

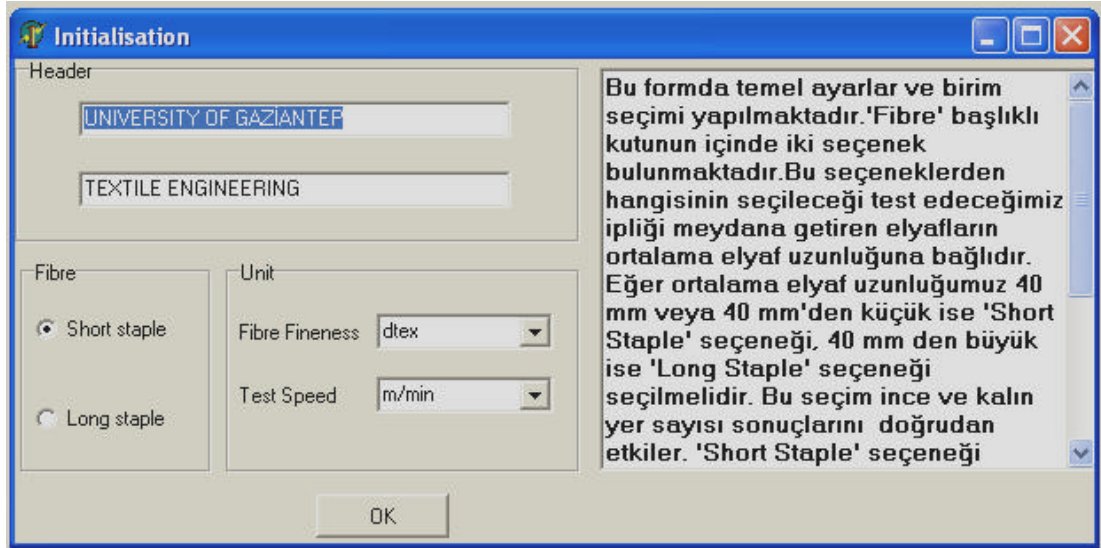


Figure 4.5. Initialization screen of software

The various parameters required to be entered in this menu are as follows.

Header: The details entered here forms the header in all reports. The mill name and location can be entered here.

Fiber: According to the staple length of the fiber which composes the material to be tested, one should select the staple length. Selection can be made by clicking in the appropriate option field, Short staple, or Long staple;

- a) Short Staple: fibers which are shorter than 40 mm
- b) Long Staple: fibers which are longer than 40 mm

In case of mix/blend, the weighted average staple length is to be calculated to arrive at the staple length of the fiber, e.g. P/V (60/40) - Polyester of 55 mm, Viscose of 35 mm staple length should be calculated as $[(55 \text{ mm} \times 60) + (35 \text{ mm} \times 40)] / 100 = 47 \text{ mm}$.

Short or long staple selection automatically alters the internal measurement conditions for assessing the imperfections. A wrong selection made will result in incorrect measurement of imperfections.

Unit: The selection made here influences the calculations in the test reports.

Fiber Fineness: Enter the unit for fiber fineness.

Available choices: dtex, microgram/inch, denier.

Test Speed: Enter the units for test speed

Available choices: m/min, y/min.

After completing the entry of these details, the button of 'OK' is clicked to exit the menu.

4.2.1.2. Count and material screen

The count, count unit and the type of the material to be tested are entered in this screen (Figure 4.6).

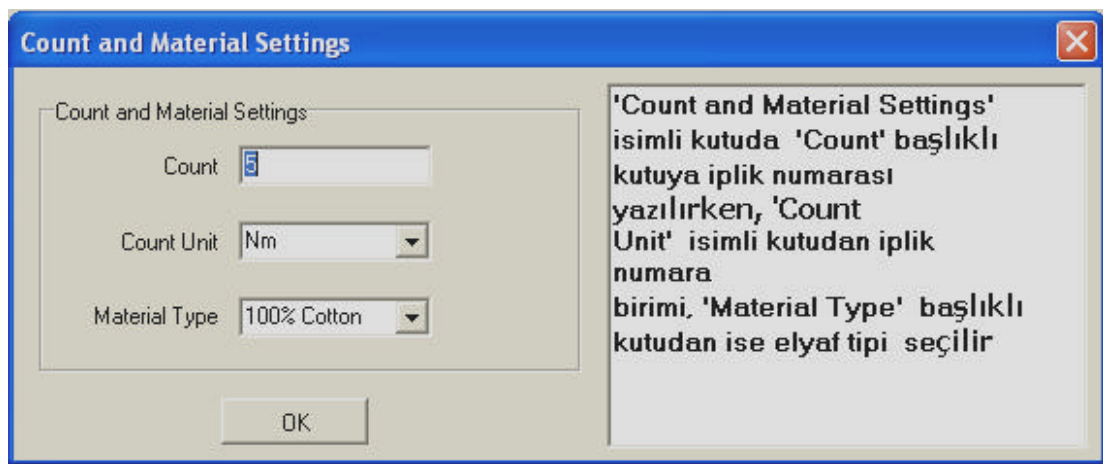


Figure 4.6. Count and Material Settings screen of software

Count: Enter the count of the yarn to be tested. If the count of yarn N_{ec} 30, enter '30' in this field.

Count Unit: Select the count unit.

Available choices: Nm, N_{ec} .

Material Type: Select the material type from the list of material listed in the drop down box.

Available choices: 100% Cotton, 100% Polyester.

4.2.2. Testing

Prior to testing, the test parameters which include important measuring conditions which are critical for measurement are to be entered. Otherwise the existing parameters will be taken for the selected test.

Testing of materials can be carried out by entering into the ‘Testing’ option in the menu bar. When the main menu of ‘Testing’ is clicked then the submenu of ‘Testing Parameters’ appears. The screen of ‘Testing Parameters’ is displayed by clicking the submenu bar of ‘Testing Parameters’ as seen in Figure 4.7 and 4.8.

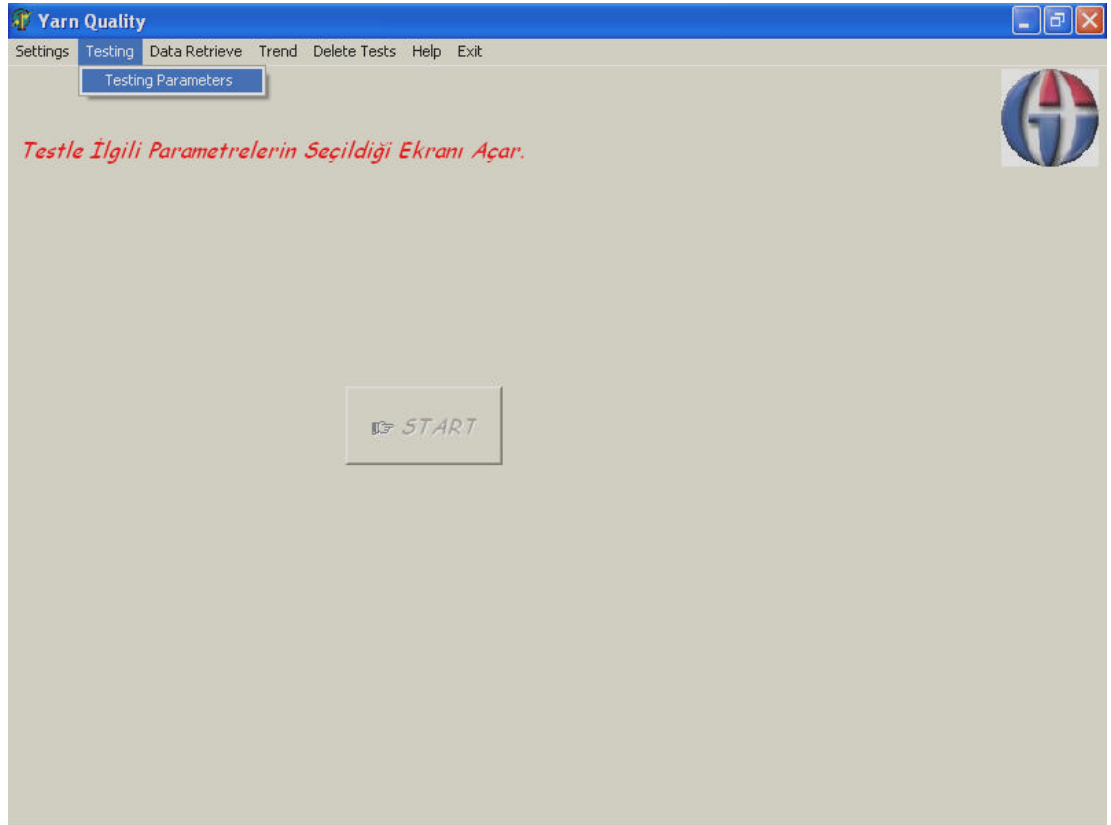


Figure 4.7. To view the screen of ‘Testing Parameters’

4.2.2.1. Identification

Details entered in 'Identification' screen (Figure 4.8) will appear as a header in all reports. A set of 5 fields, Factory Name, Yarn Type, Test Number, Operator and Comments are available which can be best used to give a clear description of the material tested. Entries can be made by clicking in the respective field. Available options of Yarn Types are 'Ring Spun' and 'O-E Spun'.

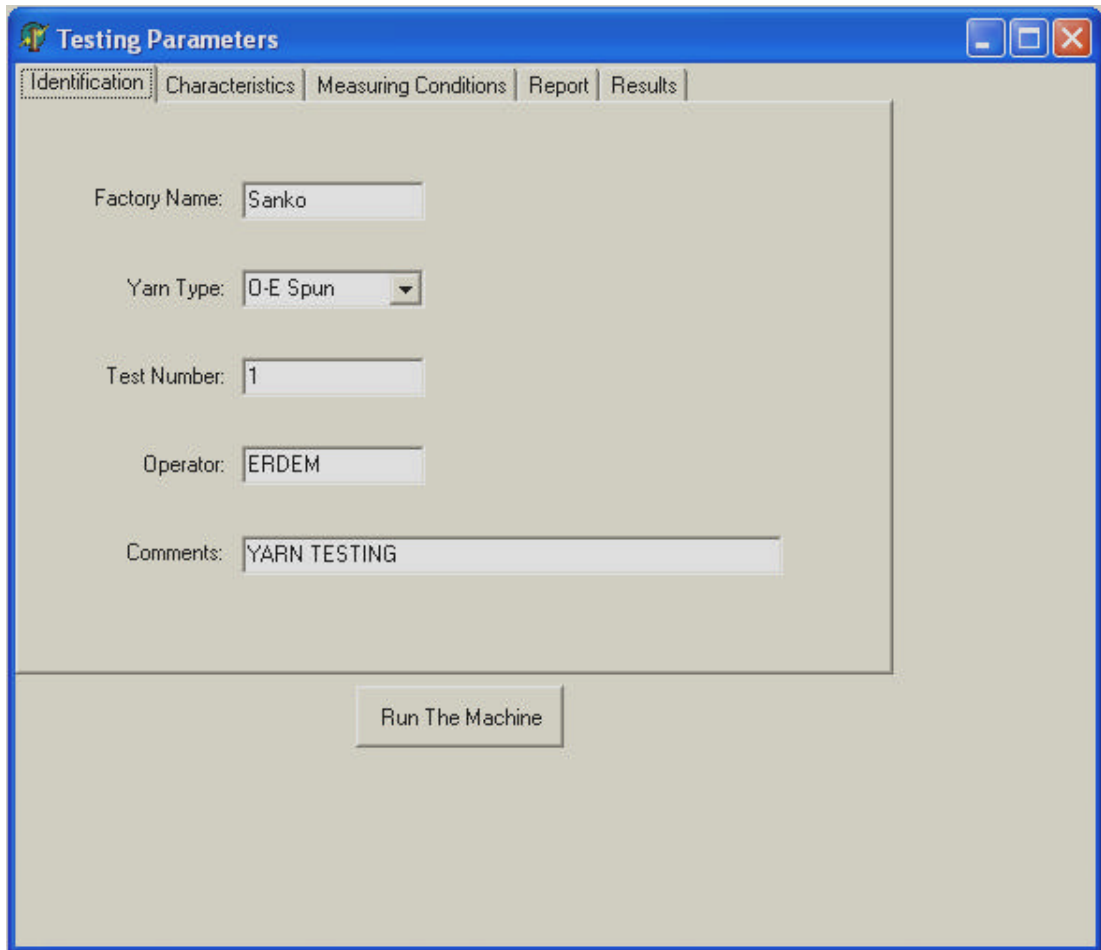


Figure 4.8. The screen of 'Testing Parameters'

4.2.2.2. Characteristics

Fineness values of fibers that compose the yarn are entered on this screen (Figure 4.9).

Testing Parameters

Identification Characteristics Measuring Conditions Report Results

Fibre Fineness and Proportions

Fibre1 Fineness: 4.5 dtex Proportion: 100 %

Fibre 2 Fineness: 0 dtex Proportion: 0 %

Run The Machine

Figure 4.9. 'Characteristics' tab of 'Testing Parameters' screen

Fiber 1 Value: Enter the fiber fineness value of the material to be tested. The fineness unit will be taken from the default values set in the Initialization screen. In case of a blend of two materials, enter the fiber fineness value of one material.

Proportion: Enter the proportion as 100, if yarn is spun from one type of material.

In case of a blend of two materials, say P/C - 67/33, if the fiber fineness of polyester is 4.23 microgram/inch and that of cotton is 3.8 microgram/inch, then the entries are to be made as follows.

Fiber 1 value - 4.23 microgram/inch, proportion 67 %

Fiber 2 value - 3.8 microgram/inch, proportion 33 %

Fields 'Fiber 2 value' and its proportion will be activated only if 'Proportion' in fiber 1 value is less than 100%.

4.2.2.3. Measuring conditions

Details regarding the test such as number of testing speed (m/min) and test duration (minute) are to be entered based on which testing will be carried out (Figure 4.10).

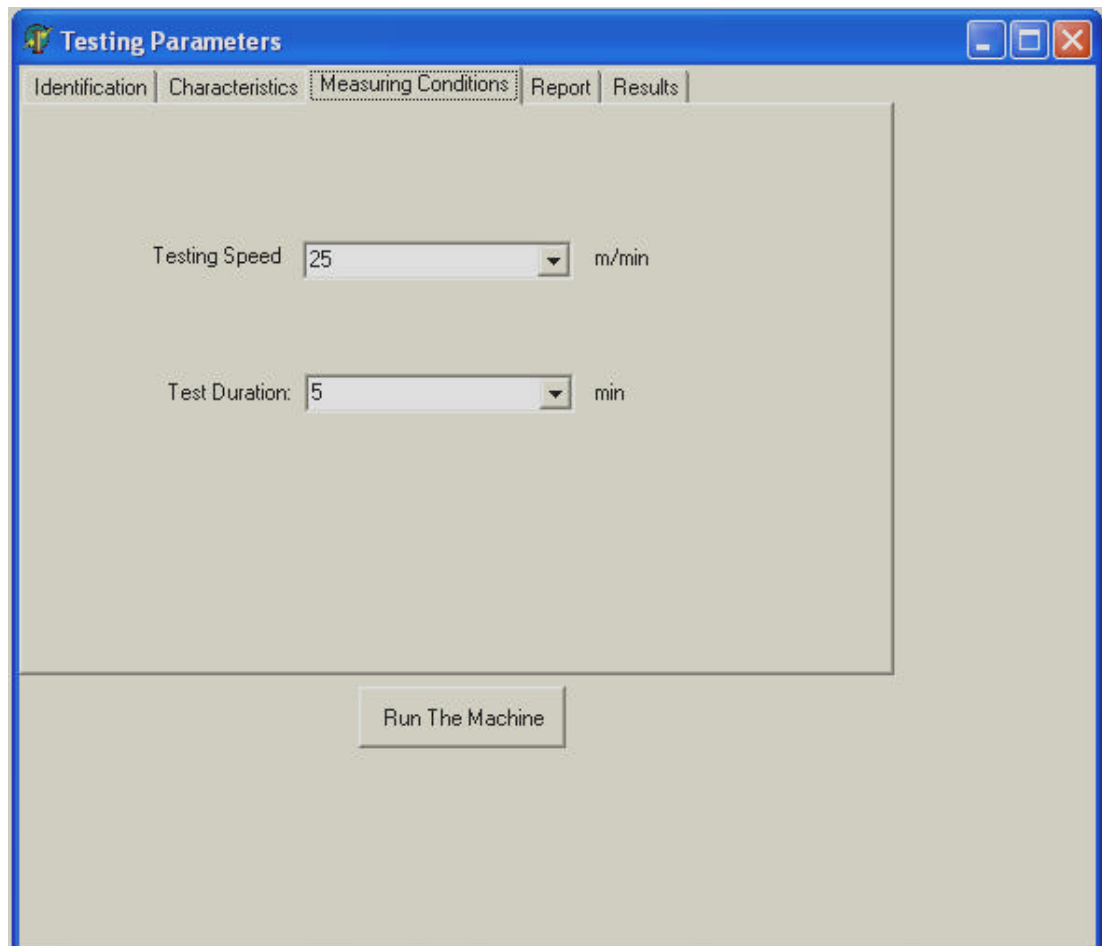
The image shows a software window titled 'Testing Parameters' with a blue title bar and standard Windows window controls (minimize, maximize, close). The window has five tabs: 'Identification', 'Characteristics', 'Measuring Conditions', 'Report', and 'Results'. The 'Measuring Conditions' tab is currently selected and highlighted. Inside this tab, there are two input fields. The first is labeled 'Testing Speed' and contains a dropdown menu with the value '25' selected, followed by the unit 'm/min'. The second is labeled 'Test Duration:' and contains a dropdown menu with the value '5' selected, followed by the unit 'min'. At the bottom center of the window, there is a button labeled 'Run The Machine'.

Figure 4.10. 'Measuring Conditions' tab of 'Testing Parameters' screen

Testing speed with which the testing is carried out is selected from the dropdown box. Test duration in minute is also selected from the appropriate dropdown box.

4.2.2.4. Report

Parameters to be reported, the fault length of thick and thin places and cut lengths for which the diagram is required are to be selected on this tab (Figure 4.11).

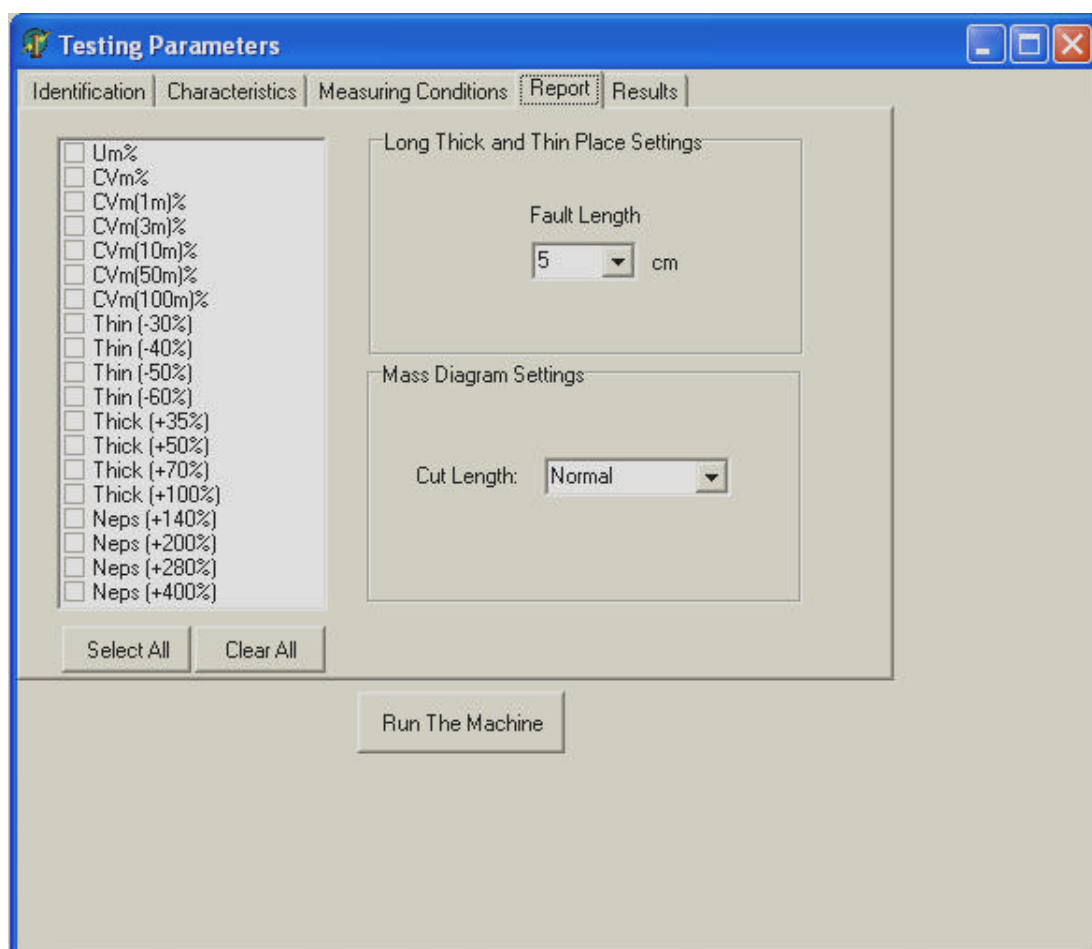


Figure 4.11. 'Report' tab of 'Testing Parameters' screen

Parameters

The required parameters can be selected or deselected by clicking on checkbox of that particular parameter in the parameters list box provided at the left side.

Long thick and thin place settings

The fault length of long thick and thin places can be selected from the dropdown box. Available options change between 5 to 200 centimeters.

Cut length

The cut length for which the mass variations are to represented in the diagram can be selected from the dropdown box. Normal cut-length refers to a cut-length of 1 cm. Other options available are; 0.02 m , 0.05 m , 0.1 m , 0.2 m , 0.4 m , 1 m , 1.5 m , 3 m , 6 m, 10 m , 25 m, 50 m, and 100 m.

4.2.2.5. Results

Selection of data file which is to be stored in the database to be retrieved any time later can be selected from the 'Results' tab of testing parameters screen. Also selection of test which is added to trend analyze can be selected from this screen (Figure 4.12).

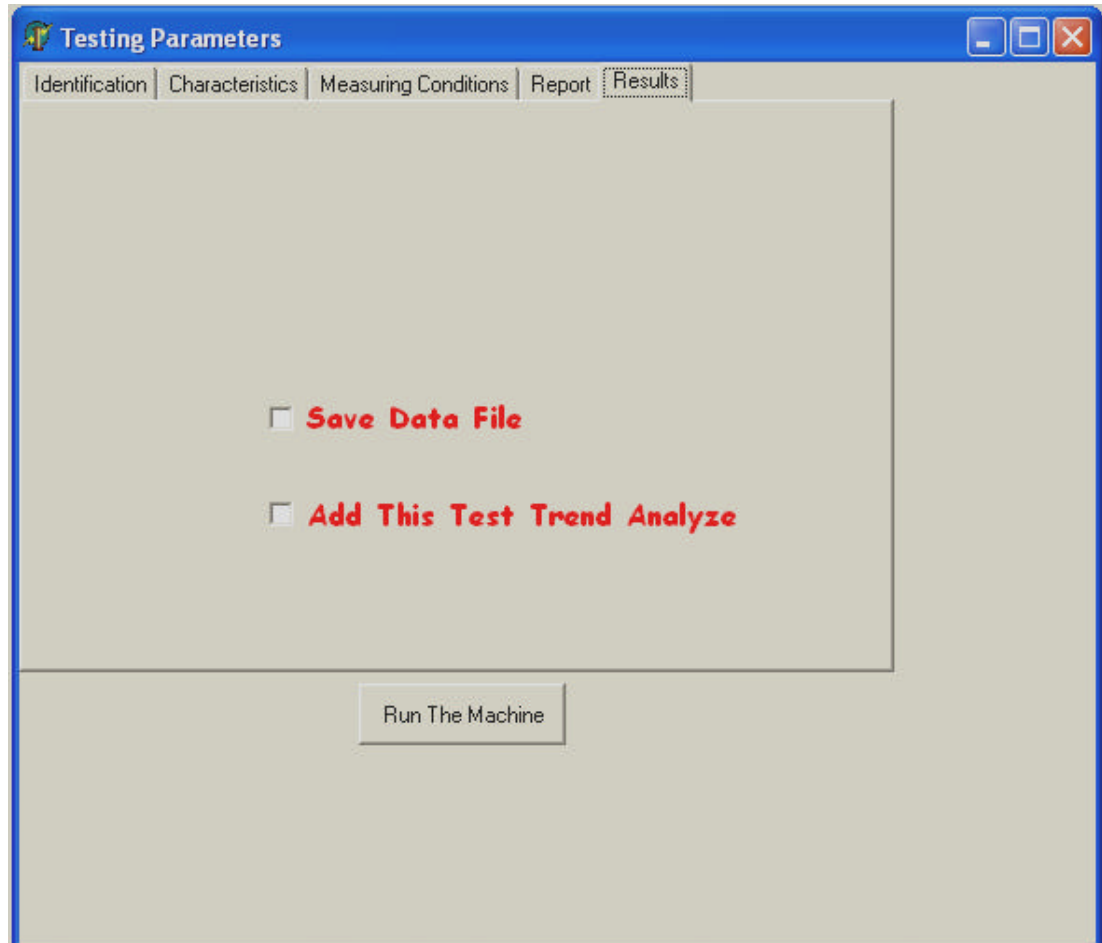


Figure 4.12. 'Results' tab of 'Testing Parameters' screen

After all testing parameters are selected; 'Run The Machine' button is clicked.

4.2.3. Test results

4.2.3.1. Quality parameters obtained

The software tests the sample for the following quality parameters.

- a) U_m %
- b) CV_m %
- c) $CV(L)$ (L 1m, 3m, 10m, 50m, 100m)

- d) Thin (-30%, -40%, -50%, -60%)
- e) Thick (+35%, +50%, +70%, +100%)
- f) Long Thin (-30%, -40%, -50%, -60%)
- g) Long Thick (+35%, +50%, +70%, +100%)
- h) Neps (+140%, +200%, +280%, +400%)

4.2.3.2. Calculation of numerical quality parameters

Each individual data obtained from optic sensors represents a constant yarn length which is named as “measuring field length” as shown in Figure 4.13.

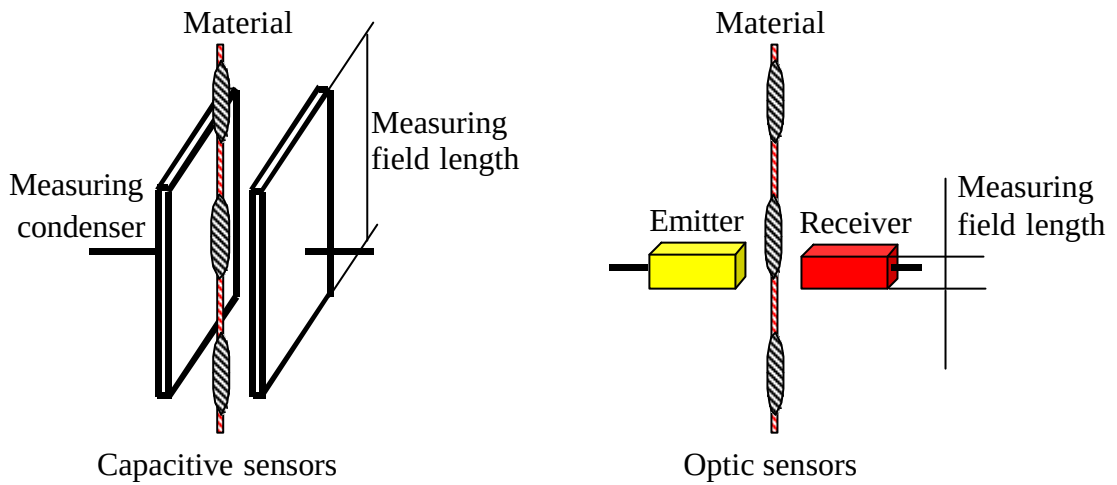


Figure 4.13. Measuring field length in capacitive and optic sensors

Available optic sensors have a measuring field length which is lower than 1 millimeter. The designed software assumes that the measuring field length of sensors is 0.5 millimeter. Namely each individual data represents a piece of yarn whose length is equal to 0.5 mm in our software as shown in Figure 4.14.

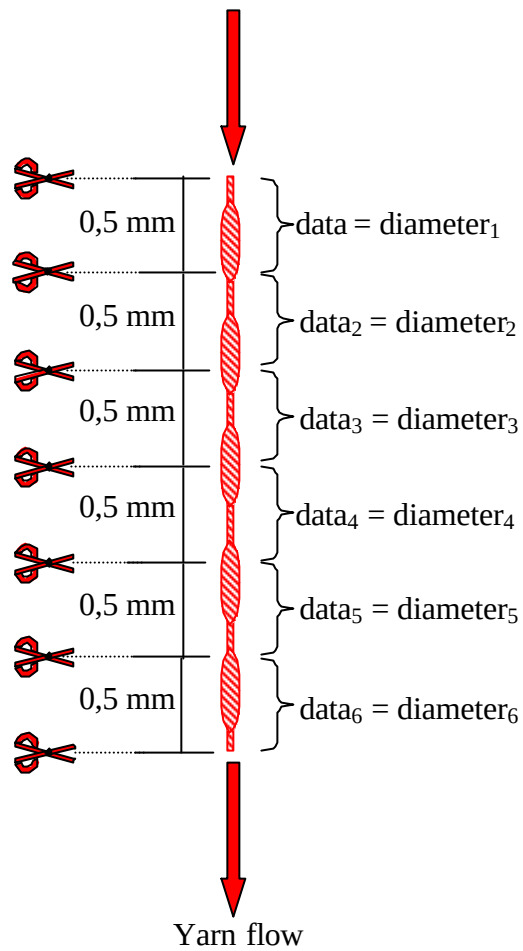


Figure 4.14. Relation between data and measuring field length

Firstly the mean value of all data loaded to software is calculated as shown in Figure 4.15. This mean value is named as “mean yarn diameter” (myd) and used in all numerical calculations and drawing graphical results.

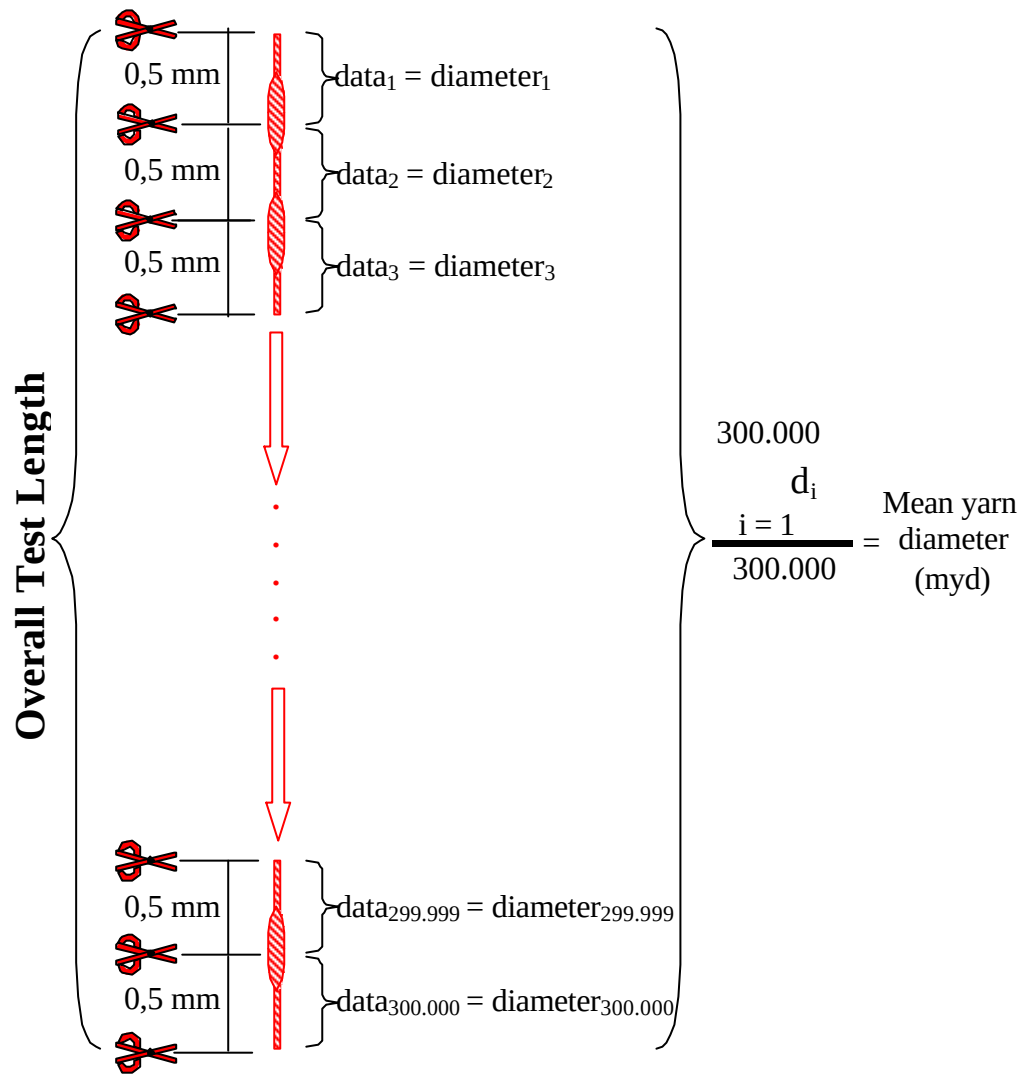


Figure 4.15. Calculation of mean yarn diameter by using overall data

Calculation of CVm% value

Because cut length value of CVm% is 1 centimeter, all data are put into groups each of whose length is 1 centimeter. 1 centimeter is equal to 10 millimeter and a 10 millimeter –yarn length is represented by (10/0.5) 20 data so each group is comprised of 20 data as shown in Figure 4.16

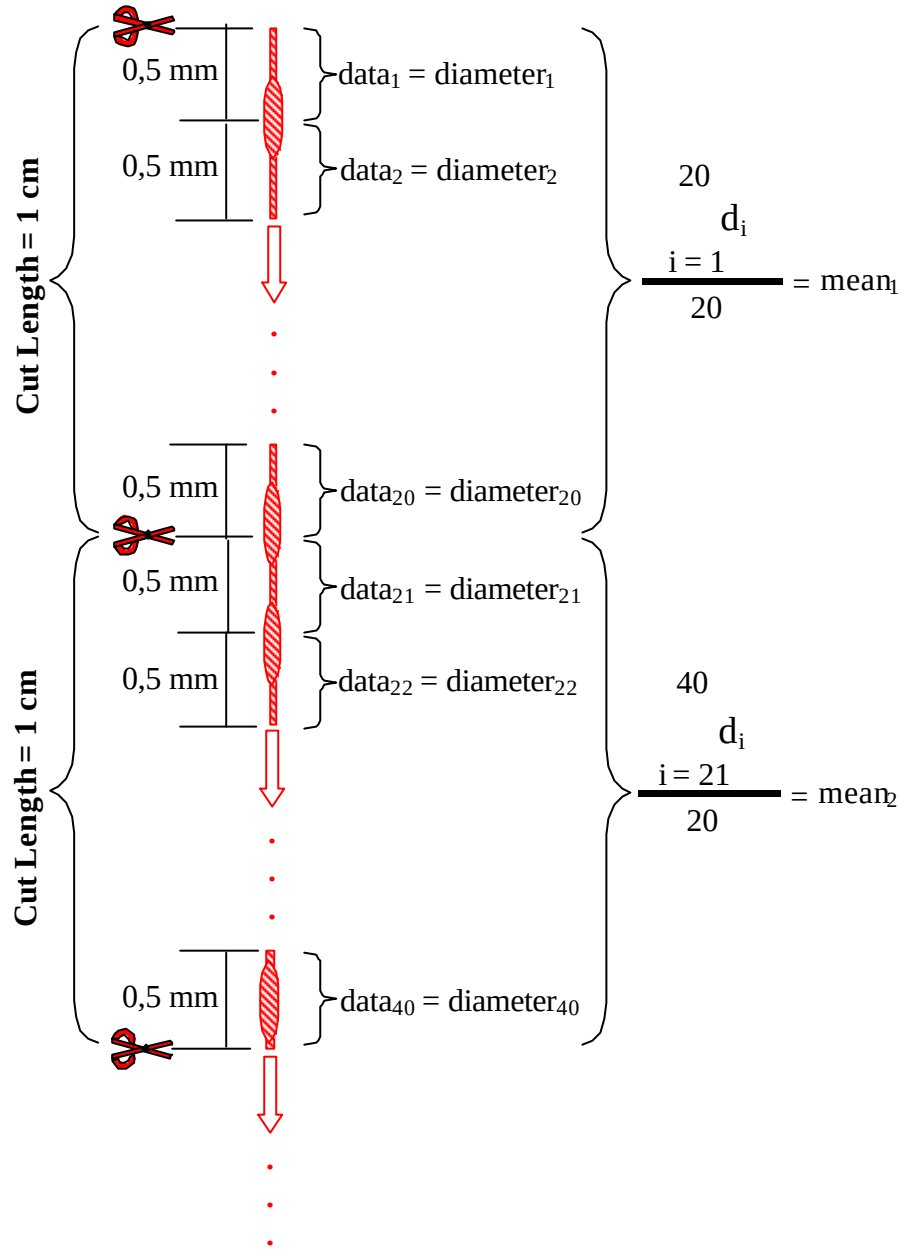


Figure 4.16. Calculation of CVm% value

And then mean value of these groups are calculated. In all tests there are totally 300.000 data. After making group and calculating mean value of these groups, $300.000/20 = 15.000$ group mean values each of which represents 1 cm yarn length are obtained. Standard deviation of these 15.000 mean values is calculated by using mean yarn diameter according to Equation 4.1.

$$\text{Standard Deviation} = \sqrt{\frac{\sum_{i=1}^{15.000} (\text{mean}_i - \text{myd})^2}{15.000}} \dots\dots\dots(4.1)$$

Where myd = “mean yarn diameter” which is calculated at first.

Finally by using “mean yarn diameter (myd)” and “standard deviation” value, CVm (1 cm) % is calculated according to Equation 4.2.

$$\text{CVm (1 cm) \%} = \frac{\text{Standard Deviation}}{\text{Mean Yarn Diameter}} \times 100 \dots\dots\dots (4.2)$$

Calculation of Um% value

Mathematical calculation method of Um% value was illustrated in details by giving an example in Chapter 3.

The coefficient of variation CVm is preferred more and more to the irregularity Um value. CVm is a parameter commonly recognized for variation at all cut lengths while Um is used to refer only to mass variations at the basic cut length (usually 1 cm).

However, till such time CVm% gains universal and sole recognition over Um%, it is essential that a proper conversion is used from one to another [36].

It can be considered that if the fiber assembly required to be tested is normally distributed with respect to its mass variation as shown in Figure 4.17, a conversion possibility is available between the two types of calculation according to the following [38]:

$$\text{CVm} = \text{Um} * 1.25 \dots\dots\dots (4.3)$$

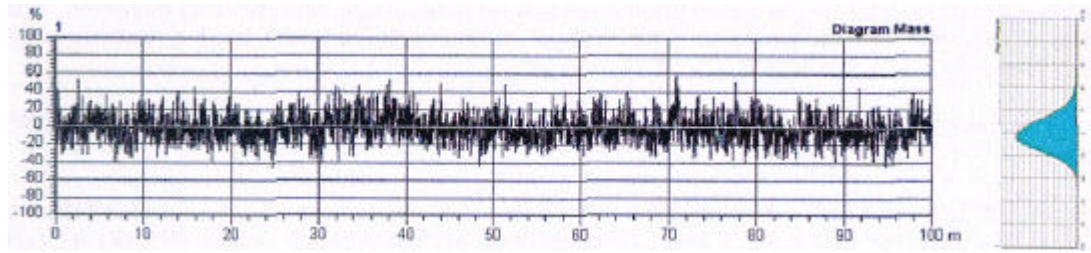


Figure 4.17. Diagram with normal distribution [38]

Designed software firstly calculates the $CVm\%$ value then uses the equation 4.3 to calculate $Um\%$ value.

Calculation of $CVm\%$ value at different cut-length

Calculation method of $CVm\%$ value at different cut-length is the same as calculation method of CVm (1 cm) explained above. Only data number in each group is changed according to cut-length as shown in Table 4.1.

Table 4.1. Data number in each group according to cut length

Cut Length	Data Number in Each Group
1 meter	2.000
3 meter	6.000
10 meter	20.000
50 meter	100.000
100 meter	200.000

If group number is lower than 13 then $CVm\%$ value is not calculated, because the test length is not enough to calculate $CVm\%$ value at this cut-length.

Calculation of thick and thin places

The fault length of thin and thick places changes according to short or long staple length selection as shown in Table 4.2.

Table 4.2. Relation between staple length and fault length of thin and thick places

Staple Length	Fault Length of Thin and Thick Places
Short Staple	30 millimeter
Long Staple	60 millimeter

Firstly all data are separated into groups. Data number in each group changes according to fault length of thin and thick places as shown in Table 4.3.

Table 4.3. Relation between staple length- fault length-data number in each group

Staple Length	Fault Length of Thin and Thick Places	Data Number In Each Group
Short Staple	30 millimeter	60 data
Long Staple	60 millimeter	120 data

After separating all data into groups, mean value of each group is calculated as shown in Figure 4.18.

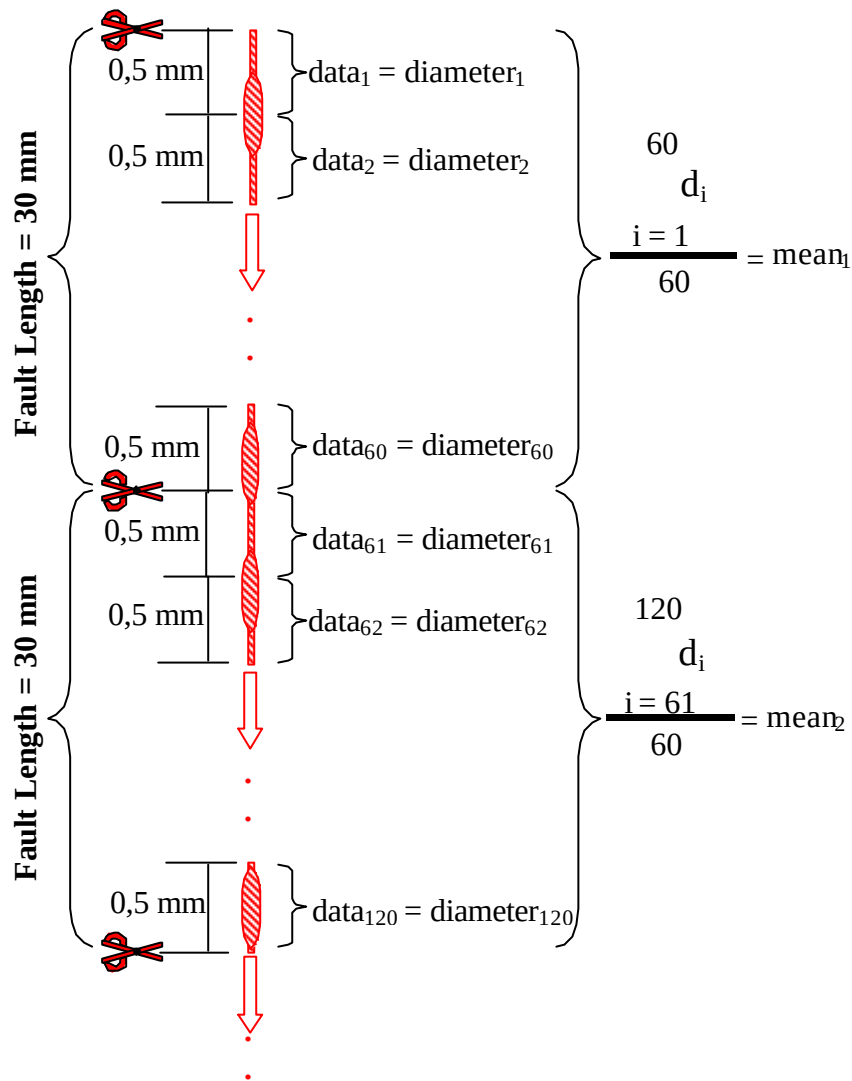


Figure 4.18. Separating a short staple yarn into groups

Deviation from mean value of each group is calculated according to Equation 4.4.

$$\text{Deviation \%} = \frac{(\text{Mean value of group}) - (\text{Mean yarn diameter})}{\text{Mean yarn diameter}} \times 100 \dots \dots \dots (4.4)$$

Calculated deviation values are compared with the defined sensitivity levels (Thin places: -30%, -40%, -50%, -60% and thick places: +35%, +50%, +70%, +100%) in a loop.

If deviation value is lower than the defined thin place sensitivity level then the number of this sensitivity level is increased one.

If deviation value is higher than the defined thick place sensitivity level then the number of this sensitivity level is increased one.

Long thin and thick place faults

Fault length of thin and thick places is constant in available evenness testers such as if staple length is lower than 40 millimeter then fault length is 30 millimeter, if staple length is higher than 40 millimeter then the fault length is 60 millimeter.

In our software separately there is an option in which different fault length can be selected in thin and thick place calculation as shown in Figure 4.19.

Length Of Long Faults:5cm		Long Faults Results Table						
Test Number	-30%	-40%	-50%	-60%	+35%	+50%	+70%	+100%
1	0	0	0	0	0	0	0	0

Figure 4.19. Long faults results table

Clearer settings, in which length and diameter yarn will be cut on winding machine, can be adjusted by inspecting long faults results.

Calculation of long faults

Calculation of long faults is the same as calculation of thin and thick places. The length of long faults ranges from 5 centimeter to 200 centimeter. According to selected fault length, the number of data in each group changes.

Calculation of neps

A nep is a very thick place in the yarn. Sensitivity limits for neps are +140%, +200%, +280%, +400%. Every time selected limit exceeded, a nep is counted. The increase for neps is calculated to a reference length of 1 millimeter. The maximum length for neps is limited to 4 millimeter. Calculation method of neps is the same as calculation method of thin and thick places as shown in Figure 4.20 and 4.21.

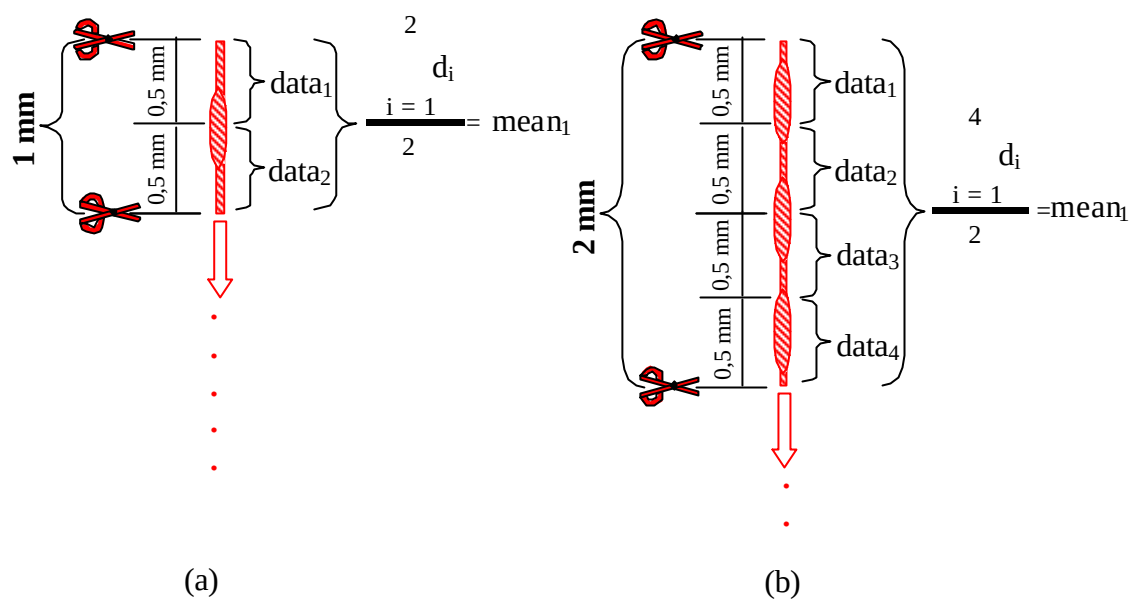


Figure 4.20. Calculation of neps in 1 mm - length (a) and 2 mm – length (b)

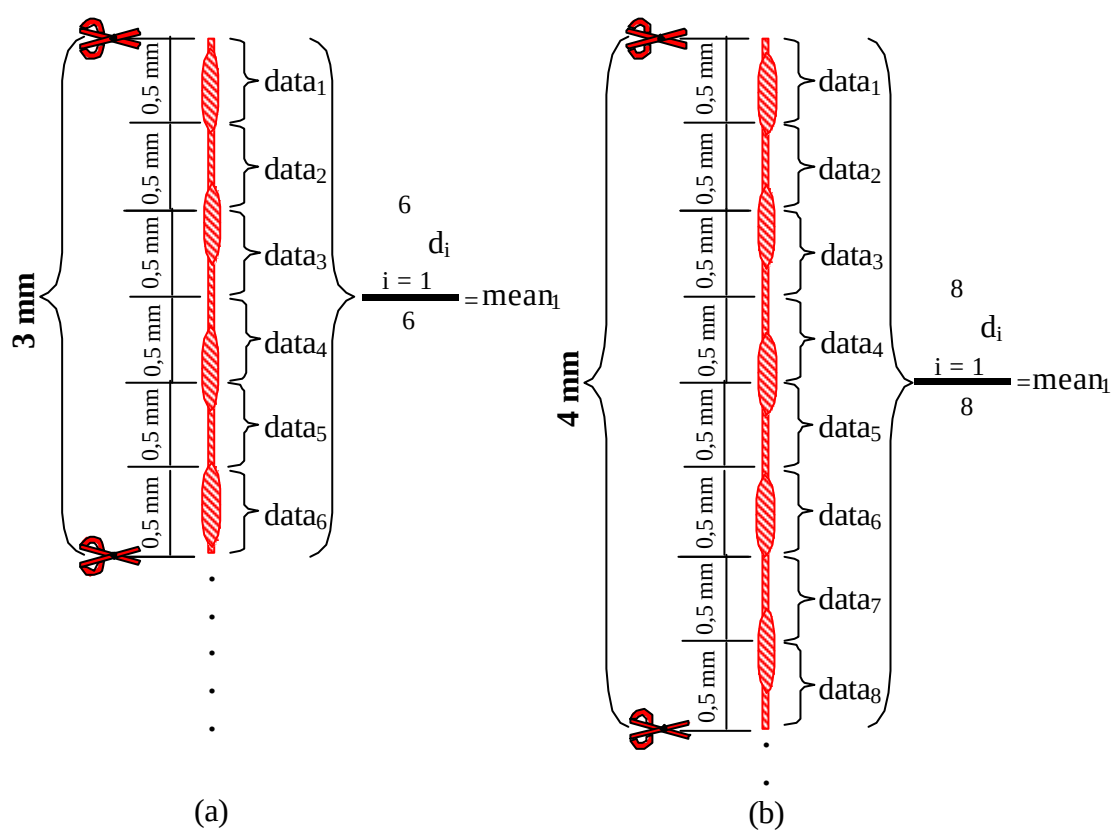


Figure 4.21. Calculation of neps in 3 mm - length (a) and 4 mm – length (b)

Deviation value of neps in each length is calculated by using mean values shown in figure 4.20 according to equation 4.4.

$$\text{Deviation \%} = \frac{(\text{mean value of group}) - (\text{mean yarn diameter})}{\text{mean yarn diameter}} \times 100 \dots\dots\dots(4.4)$$

Every time the deviation exceeds the selected nep limit, a nep is counted for this nep limit.

4.2.3.3. Numerical report

A typical results screen showing numerical report is shown in figure 4.22.

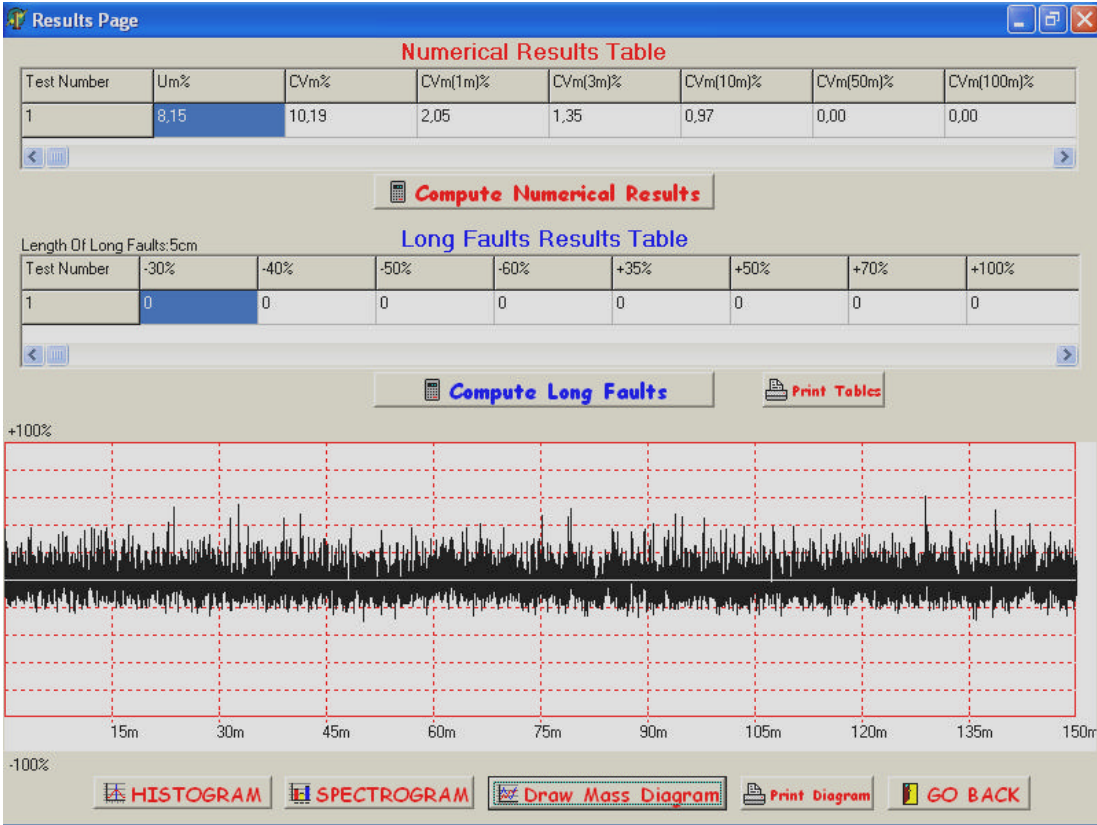


Figure 4.22. ‘Numerical Results’ screen

A printout of the numerical results is given in Figure 4.23.

**UNIVERSITY OF GAZİANTEP
TABULATED RESULTS**

Factory Name : Selçuk İplik	Operator : ERDEM	Staple Length : Short staple
Yarn Type : Ring Spun	Test Date : 23.12.2004	Fibre 1 Fineness : 3,5 microgram/inch
Test Number : 4	Test Time : 12:01:34	Fibre 1 Proportion : 100 %
Count : 30 Nec	Test Speed : 25 m/min	Fibre 2 Fineness : 0 microgram/inch
Material Type : 100% Cotton	Test Duration : 5 min	Fibre 2 Proportion : 0 %
Comments : Ne 30		

NUMERICAL RESULTS

Test Number	1
Um%	10,58
CVm%	13,23
CVm(1m)%	3,72
CVm(3m)%	3,18
CVm(10m)%	3,04
CVm(50m)%	0,00
CVm(100m)%	0,00
Thin (-30%)	8
Thin (-40%)	0
Thin (-50%)	0
Thin (-60%)	0
Thick (+35%)	64
Thick (+50%)	8
Thick (+70%)	0
Thick (+100%)	0
Neps (+140%)	736
Neps (+200%)	176
Neps (+280%)	48
Neps (+400%)	0

LONG FAULTS (Length Of Long Faults: 5cm)

Test Number	1
-30%	0
-40%	0
-50%	0
-60%	0
+35%	0
+50%	0
+70%	0
+100%	0

Figure 4.23. A printout of numerical results

4.2.3.4. Graphical reports

The following graphical reports are obtained in the software.

- Diameter diagram.
- Diameter spectrogram.
- Diameter histogram.

Drawing diameter diagram

Firstly all data are separated into groups according to selected cut-length value for diagram, and then mean value of each group is calculated. Amplitude value of each group is calculated with respect to “mean yarn diameter” according to equation 4.4.

$$\text{Deviation \%} = \frac{(\text{mean value of groups}) - (\text{mean yarn diameter})}{\text{mean yarn diameter}} \times 100 \dots \dots \dots (4.4)$$

Finally, deviation values are carried on the graphic according to their plus or minus sign as shown in Figure 4.24.

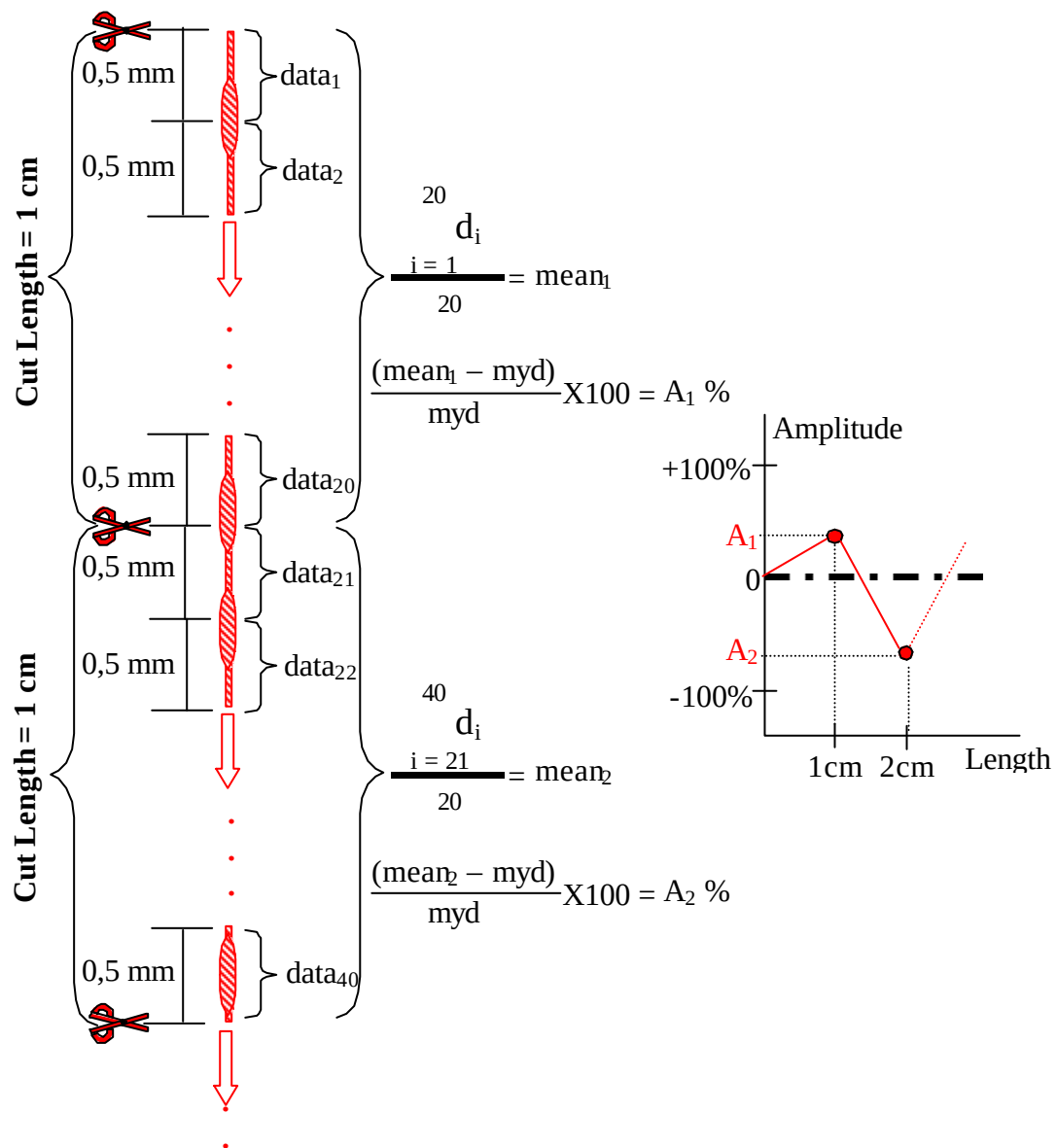


Figure 4.24. Drawing diameter diagram for cut length 1 cm

Drawing diameter spectrogram

The spectrogram is a graphical representation specifically designed for identification and analysis of the periodic faults. It is a representation of the mass variations in the frequency domain

If a periodic fault occurs in the fiber material with the frequency f_1 , this leads to a peak in the spectrogram at the position f_1 as shown in Figure 4.25.

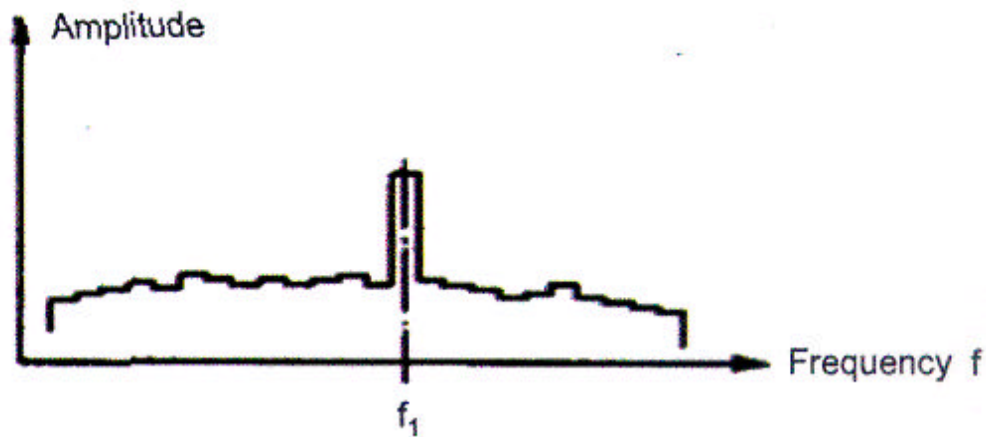


Figure 4.25. Spectrogram: Representation of mass variations in the frequency domain [38]

The frequency spectrum is not very practical for textile trials. It is preferred that a representation which makes reference to the wavelength for such trials. Between frequency and wave-length there is a simple relationship:

$$f = \frac{v}{l} \dots\dots\dots (4.5)$$

f = frequency (s^{-1})

λ = wavelength (m)

v = material speed (m/s)

A yarn fault is said to be periodic if it repeats continuously in a yarn at fixed lengths as shown in Figure 4.26

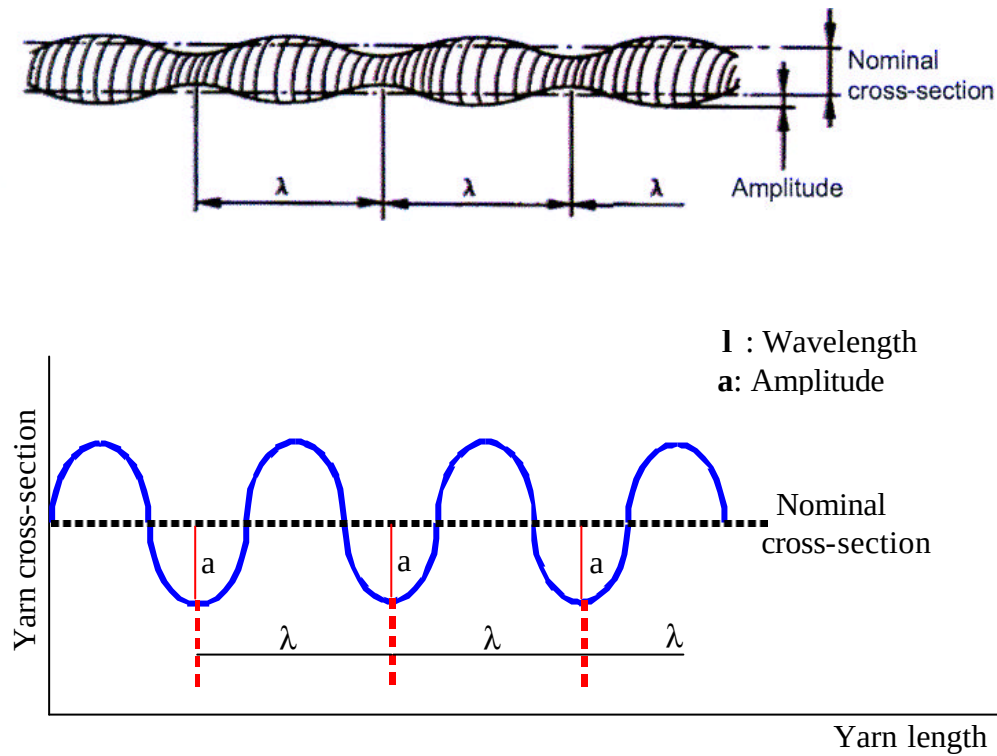


Figure 4.26. A periodic fault and its representation on diameter diagram [38]

The wave-length indicates directly at what interval the periodic faults repeat. The exact designation for the curve is the wave-length spectrum as shown in Figure 4.27.

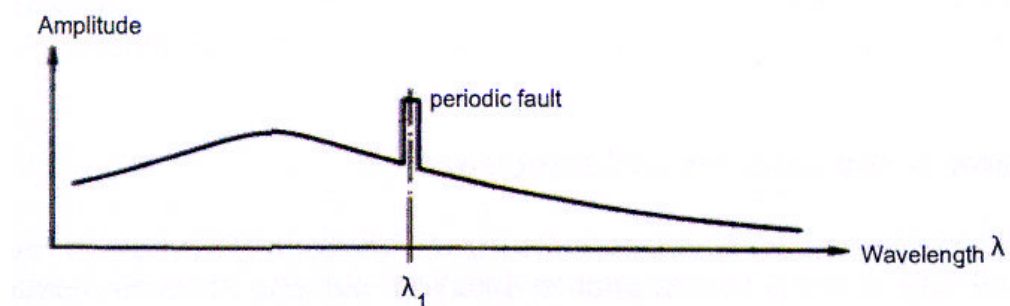


Figure 4.27. Spectrogram with periodic fault [38]

The wave-length spectrum is theoretically a continuous curve. Technically, it is not possible to investigate each separate frequency (or wave – length); therefore the number of wave -length must be limited. A yarn sample was tested with maximum yarn speed (400 m/min) and maximum evaluation time (20 min) on Premier Tester 7000 to define the number of wave – length of spectrogram. The number of wave – length of spectrogram of this test was counted and each wave – length value was noted. These waves – length values were used to design the software.

An amplitude value is calculated for each wave-length value in drawing spectrogram
Calculation of amplitude value is performed like this;

Selection of data is successively performed at a defined interval which is named as wave – length. After selection of data, mean value of the selected data is calculated. Absolute of difference between mean value of selected data and the mean yarn diameter gives out the amplitude value of this wave-length value as shown in Equation 4.6.

$$\text{Amplitude} = \left| (\text{mean value of selected data}) - (\text{mean yarn diameter}) \right| \dots\dots\dots (4.6)$$

Calculated amplitude value and wavelength of this amplitude value are placed on vertical and horizontal axes of graphic respectively as shown in Figure 4.28. This procedure is repeated for all wavelengths. If repeat number of interval is lower than eight, then spectrogram is not drawn for this wavelength.

A spectrogram drawn by designed software for Ne 20 yarn is given in Figure 4.29 as an example.

Drawing diameter histogram

The first step of histogram draw is to prepare frequency distribution. The procedure of frequency distribution is first to note the range of the observations (data), the difference between the highest and the lowest observations, then divided into several sub-ranges or class intervals. Each individual data is considered and put into the correct class interval, and the class frequency is then the number of observations that occur in a particular class interval. Table 4.4 shows how 100 count-test results have been entered into a frequency distribution [5].

Table 4.4. Frequency distribution of count – test results

Class Interval		Class Frequency
59-60	II	2
61-62		0
63-64	III	3
65-66	~~II~~ I	6
67-68	~~II~~ ~~II~~ I	12
69-70	~~II~~ ~~II~~ ~~II~~ III	18
72-72	~~II~~ ~~II~~ ~~II~~ ~~II~~ III	23
73-74	~~II~~ ~~II~~ ~~II~~ I	16
75-76	~~II~~ ~~II~~ II	12
77-78	III	4
79-80	III	3
81-82	II	2

The class interval is recorded as range such as 65-66. Its real range is from 64,5-66,4. Thus a result of 64,9 is a straightforward case for entry into the 65-66 class interval. A result of 64,3 is entered into the 63-64 class interval. A result of 66,5 is entered into the class interval 67-68.

If mid-values of class intervals and related class frequencies are carried on horizontal and vertical axis of a co-ordinate system respectively, then frequency polygon is obtained as shown in Figure 4.30.

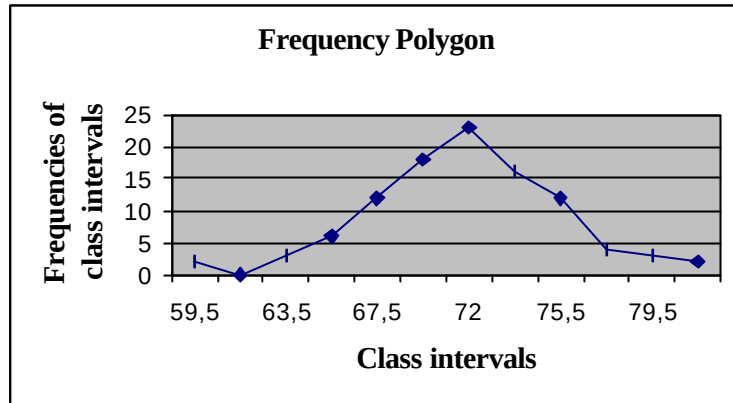


Figure 4.30. A frequency polygon produced from the data in Table 4.4

In a histogram, the data are presented as a series of rectangles erected over the horizontal scale. The width of a rectangle is the class interval, and its area represents the class frequency. When the class intervals are of equal width, as they commonly are, then the heights of the rectangles will be proportional to the class frequencies. Figure 4.31 shows the construction of a histogram from the data in Table 4.4 [22].

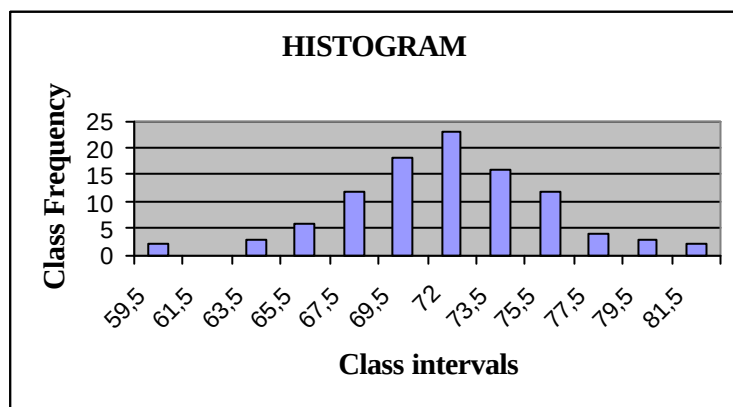


Figure 4.31. A histogram produced from data in Table 4.4

The procedure is similar to that for the frequency polygon, but instead of points being plotted, horizontal lines are drawn at the corresponding class frequencies, the lines extending across the limits of the class intervals.

As the number of data recorded becomes higher and the class intervals become smaller, both the frequency polygon and the histogram assume the appearance of a smooth curve [5, 22] (Figure 4.32).

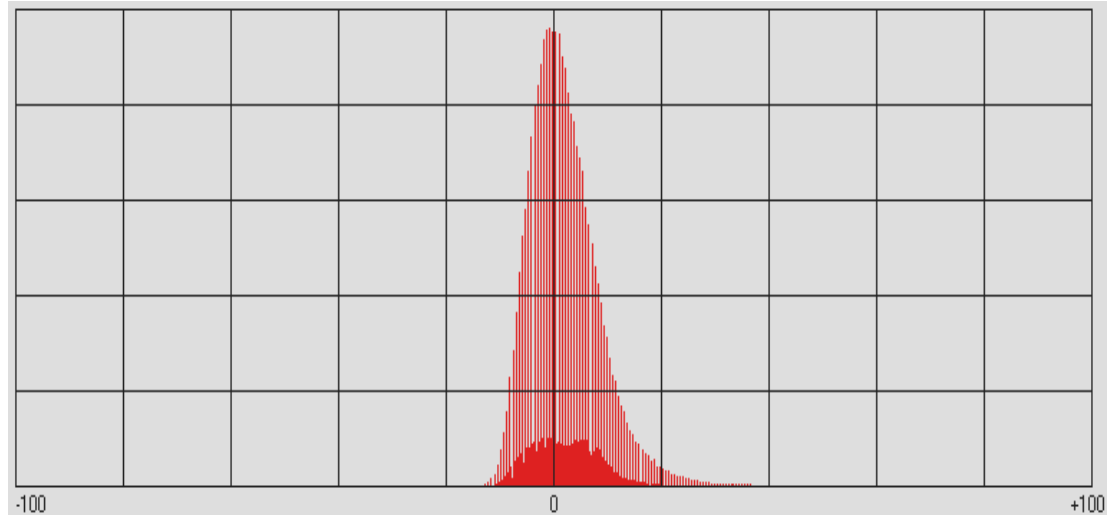


Figure 4.32. A histogram drawn by designed software for 20 Ne yarn

4.2.4. Data retrieve

The main menu of ‘Data Retrieve ‘ has two submenus such as ‘New Test’ and ‘Old Tests’.

4.2.4.1. New test

When ‘New Test’ is clicked ‘Testing Parameters’ screen is displayed. After entering all test parameters on this screen, the test can be commenced by clicking the ‘Run The Machine’ button.

4.2.4.2. Old tests

The ‘Old Tests’ screen provides for viewing of any of the results stored in the software (Figure 4.33).

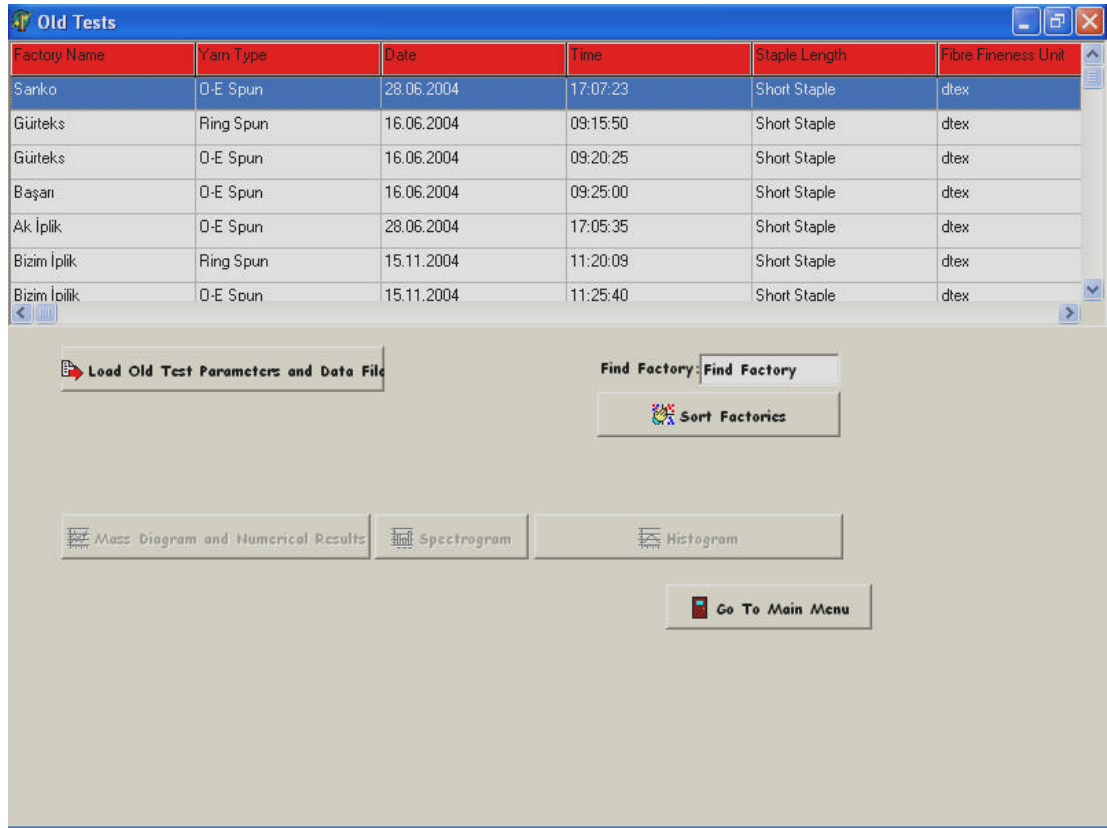


Figure 4.33. ‘Old Tests’ screen

When “Load Old Test Parameters and Data File” button is clicked, the test parameters and data file of selected row on the table are loaded to the software and results buttons become active. By clicking results buttons the related results can be displayed.

Any factory on the table can be found by writing the relevant factory name in the “Find Factory” box.

The names of factories can be sorted by clicking “Sort Factories” button.

4.2.5. Delete tests

“Delete Tests” screen is used for deleting the data file and test parameters of unwanted tests (Figure 4.34).

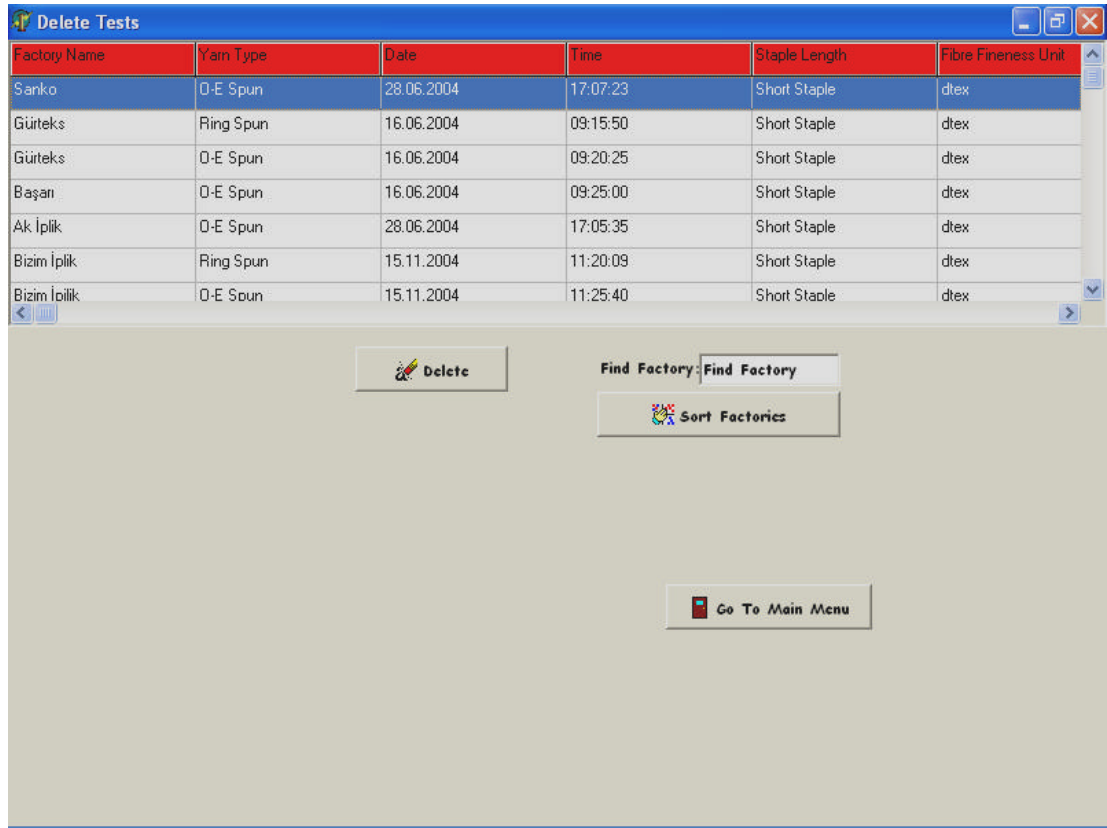


Figure 4.34. ‘Delete Tests’ screen

When “Delete” button is clicked, the test parameters and data file of selected row on the table are deleted from the software.

Any factory on the table can be found by writing the relevant factory name in the “Find Factory” box.

The names of factories can be sorted by clicking “Sort Factories” button.

4.2.6. Trend

Consistency in quality is an essential requirement to get a hold in the market which has become highly competitive. This requires a constant check over the quality trend for a period. The screen wherein the trend can be analyzed as is shown in Figure 4.35.

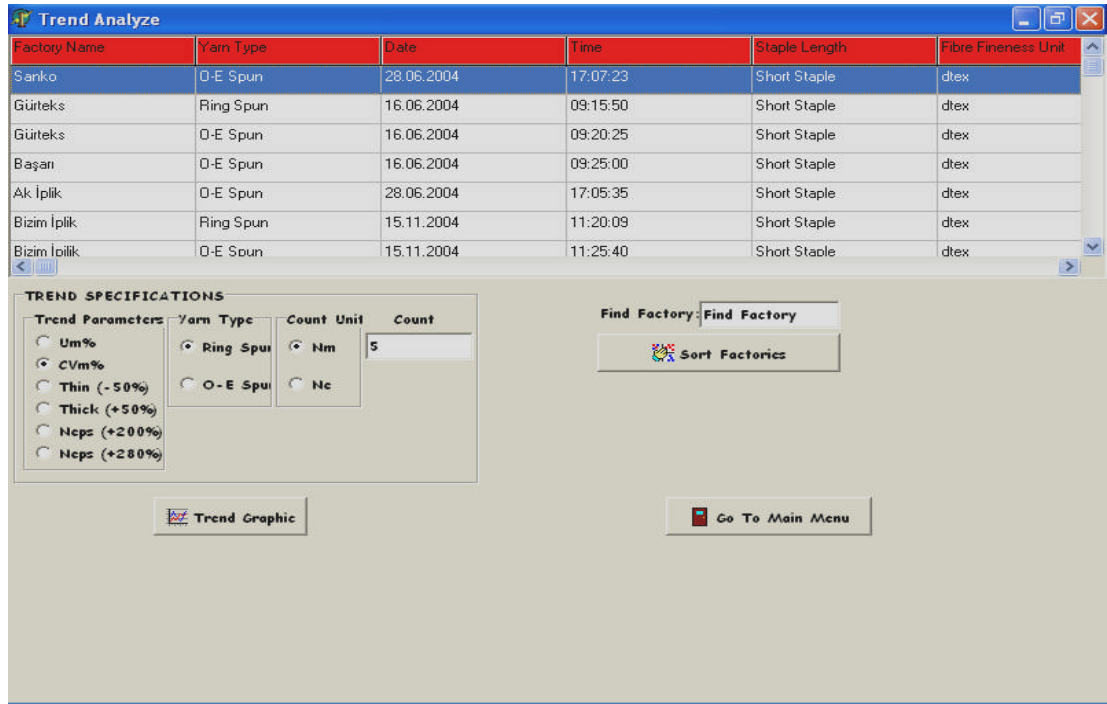


Figure 4.35. “Trend Analyze” screen

The tests of selected factory are analyzed according to trend specifications. After all trend specifications are selected, the trend graphic can be displayed by clicking the “Trend Graphic” button as shown in Figure 4.36.

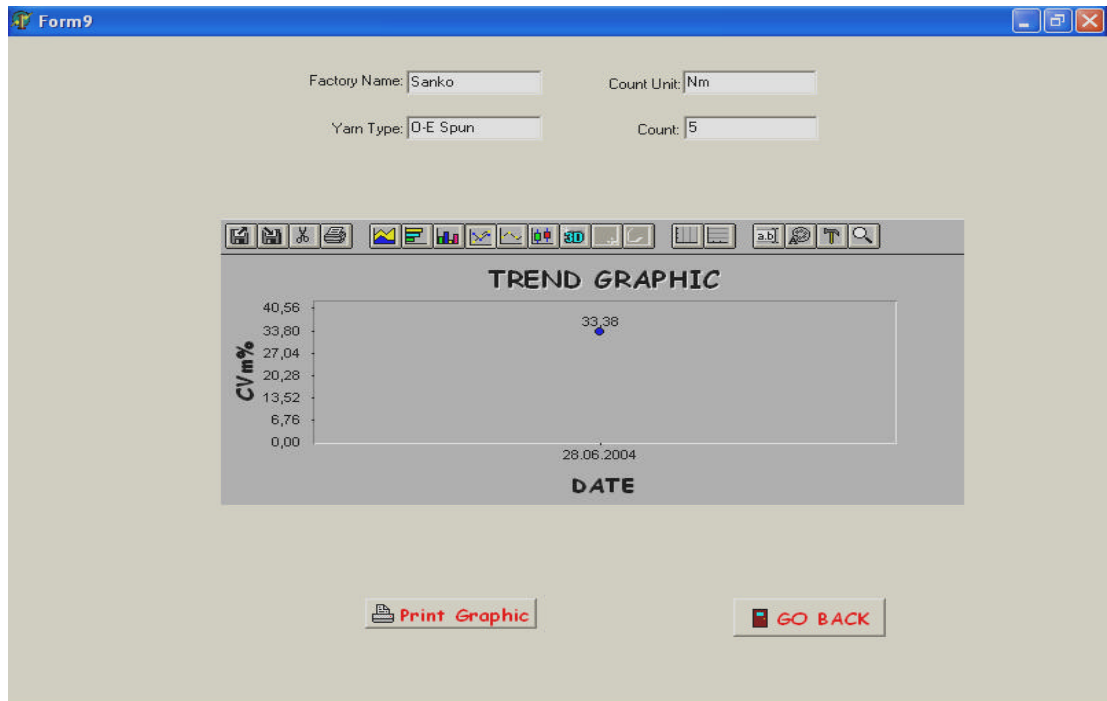


Figure 4.36. Trend graphic

CHAPTER 5

EXPERIMENTAL SET-UP AND EXPERIMENTAL STUDY

5.1. Introduction

A yarn has to pass from all subsequent processes without any harm, because yarn quality determines the appearance of knitted and woven fabrics.

Spinners directed their mills without testing devices for quality control over years, because the technology was not available for sophisticated measuring systems. The first evenness tester for yarns was not developed until after the Second World War. This testing system contributed greatly to the improvement of the yarn quality. Although the speed of textile machines such as cards and draw frames increased by 10 to 20 times between 1950 and the year 2000, the evenness of yarns has improved dramatically during the same period. It would not be possible to use the yarns today on modern weaving and knitting machines without this progress.

The textile measuring technology has also developed fast. The evenness tester of 1948, which only could represent the evenness of yarns, rovings, and slivers with a diagram recorder, up to the evenness tester of today was a long way to go [38]. In this study, a software which analyzes mass variation of yarns designed.

5.2. Experimental Setup

In order to be able to monitor and to evaluate thick and thin places as well as deviations from the desired yarn diameters, the thickness of the yarn must be converted into a proportional electrical voltage. The course of the voltage is called as 'yarn signal'.

Experimental setup is shown in Figure 5.1. It was consisted of yarn thickness measuring unit (sensors), the table (sensors stand) and A/D converter card to convert analog signal into digital signal and the Premier Tester 7000. Sensors were put on the rail of sensors stand, which was placed under the capacitor plates of Premier Tester 7000. The drive system of Premier Tester 7000 was used to flow the yarn through the

sensors in order to simplify the experimental set-up. Apart from drive system, the parts of the experimental setup were explained in the following sections.



Figure 5.1. Experimental setup

5.2.1. Yarn thickness measuring unit (sensors)

The most important part of the experimental setup is yarn thickness measuring device. This device measures the thickness of the yarn. The most suitable place to situate the measuring unit on the Premier Tester 7000 is just under the capacitor plates.

Figure 5.2 and 5.3 show yarn thickness measurement unit (sensors).



a



b

Figure 5.2. (a-b) Yarn thickness measurement unit (sensors)

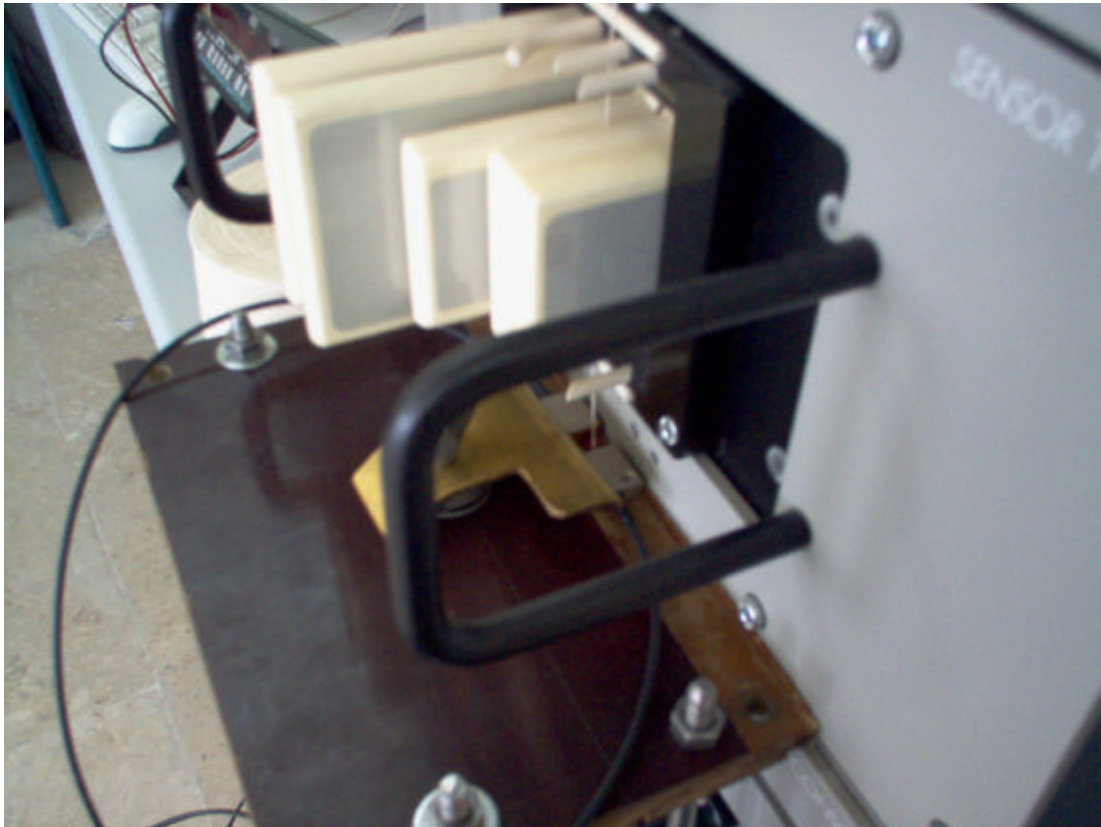


Figure 5.3. Yarn thickness measurement units (sensors)

The emitter and the receiver have been so arranged that they look face to face at a distance of 6 mm. The emitter produces a beam of light while the receiver generates an electric signal (DC voltage) which is proportional to the received beam of light. A voltage drop on the electric signal will be occurred, since some part of the light are blocked by the yarn, therefore, the difference in the electric signal corresponds to the thickness of the yarn. The sensor reads the thickness of the yarn as analog signals,

and an analog/digital (A/D) converter card converts these analog signals into digital data to store them in the hard disk of a personal computer. The trigger time of the A/D converter has been set to 1 millisecond. This matches 1000 digital data during each one second. All the data, stored in the hard disk, were used to determine the evenness of the yarns by means of the software in a numeric and graphic environment as shown in Figure 5.4.

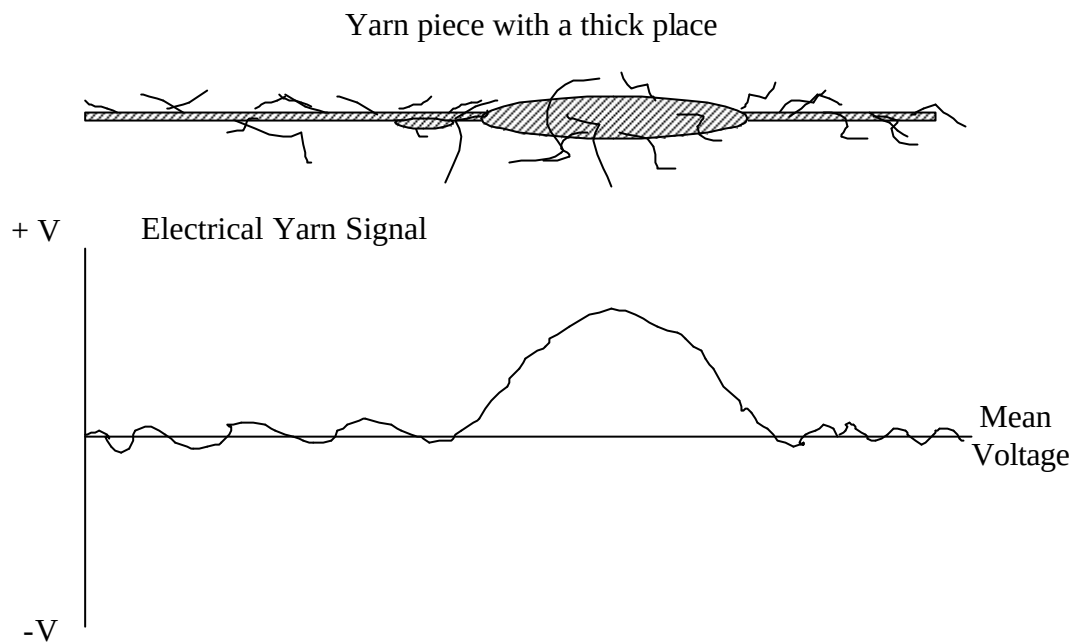


Figure 5.4. An electrical yarn signal for a thick place

In the yarn evenness measuring systems, the conversion is performed either with the sensor of the capacitive measuring principle or with the sensor of the optical measuring principle. The sensor is part of the intelligent measuring head, which also consists of the electronic system to convert mass or diameter variations into an electric signal. There are two measuring principle of sensors.

5.2.1.1. The capacitive measuring principle

The yarn signal corresponds to the yarn mass in the capacitive measuring principle. An electrical field is produced in the sensor slot between a pair of capacitor plates. If the mass of yarn between the capacitor plates changes, the electrical signal is altered and the output signal of the sensor changes accordingly. The result is an electrical

signal variation proportional to the mass variation of the test yarn passing through (Figure 5.5).

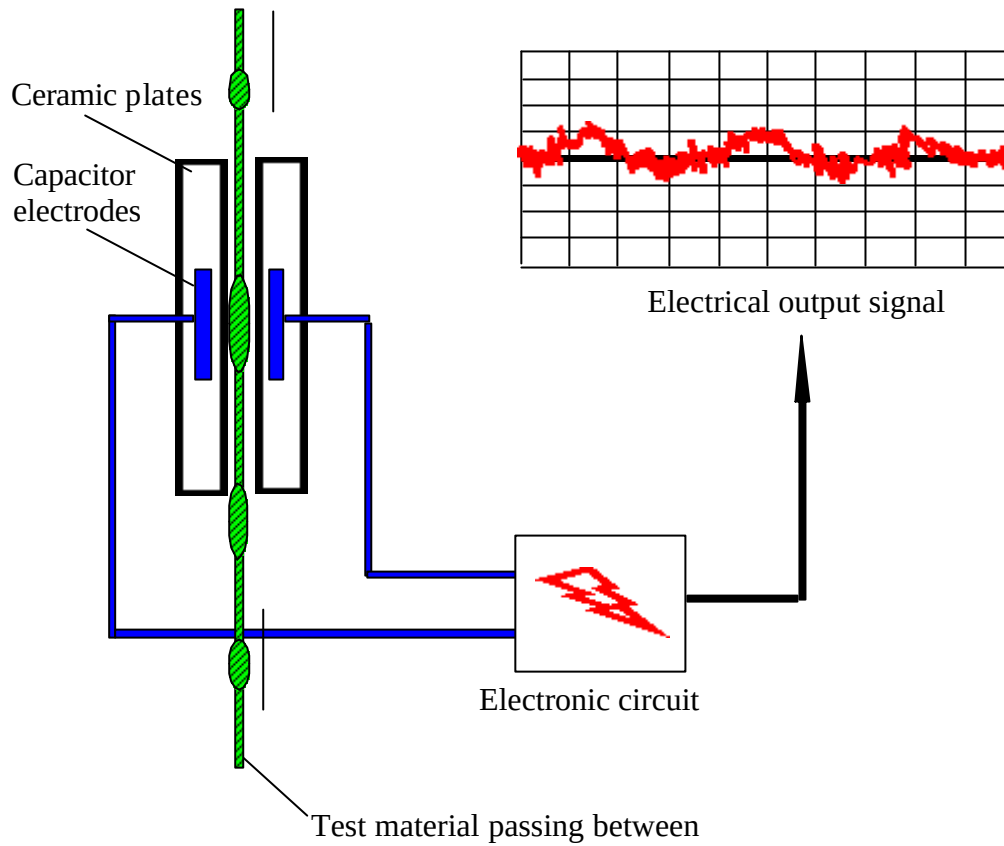


Figure 5.5. Capacitive measuring principle

5.2.1.2. The optical measuring principle

With the optical measuring principle, the yarn signal corresponds to the diameter of the usually round yarn, which is located inside the measuring field. Changes of the yarn diameter cause a proportional change of the yarn signal (Figure 5.6).

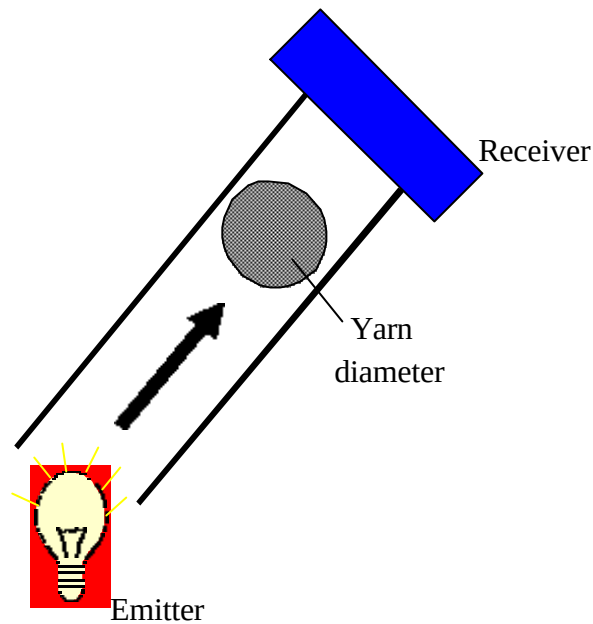


Figure 5.6. Optical measuring principle

The infrared light source (emitter) and the photocell (receiver) constitute the sensor for the optical measuring of the yarn diameter. The emitter sends the infrared light, which reaches the receiver. The receiver emits a voltage, which is proportional to the amount of light. If a yarn is brought in the light field, the yarn will block parts of the light then the amount of the light, which reaches the receiver, reduces. From this reduction, an electrical signal is obtained. There are two types of optical measuring principle;

One-dimensional measuring principle

One-dimensional measuring principle is shown in Figure 5.7. With this measuring principle, the diameter variation of yarn is determined by using only one source of illumination. This measuring method is subject to disturbing influences due to shape effects. This approach is only correct with yarns of approximately round cross-section. Any deviations from the ideal, circular cross-section result in incorrect measurement values, because the non-circular shape is responsible for a large part of the signal, which has been interpreted as a diameter variation and therefore results in incorrect data in the thick and thin places.

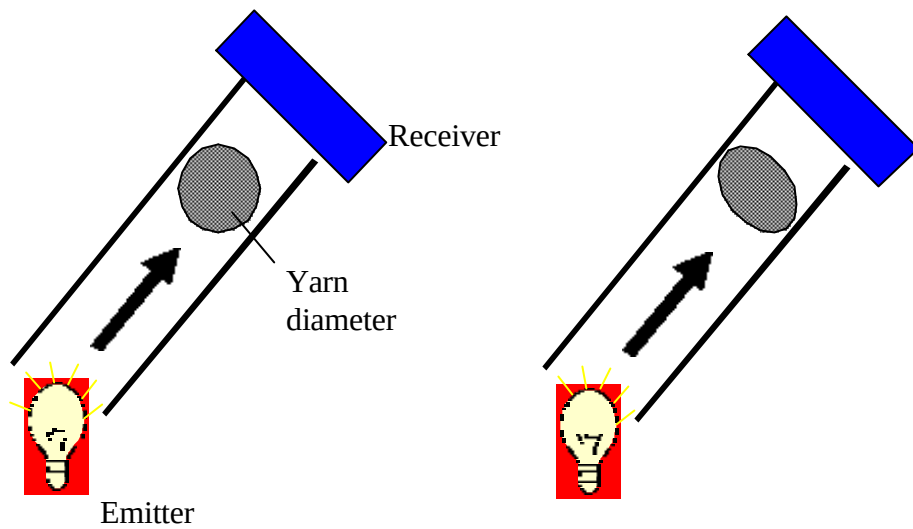


Figure 5.7. One-dimensional measuring principle

Two-dimensional measuring principle

Two-dimensional measuring principle is shown in Figure 5.8. With this measuring principle, the diameter is measured from two sides, by means of a cross-wise placement of optical transmitters, mirrors and receivers on each side.

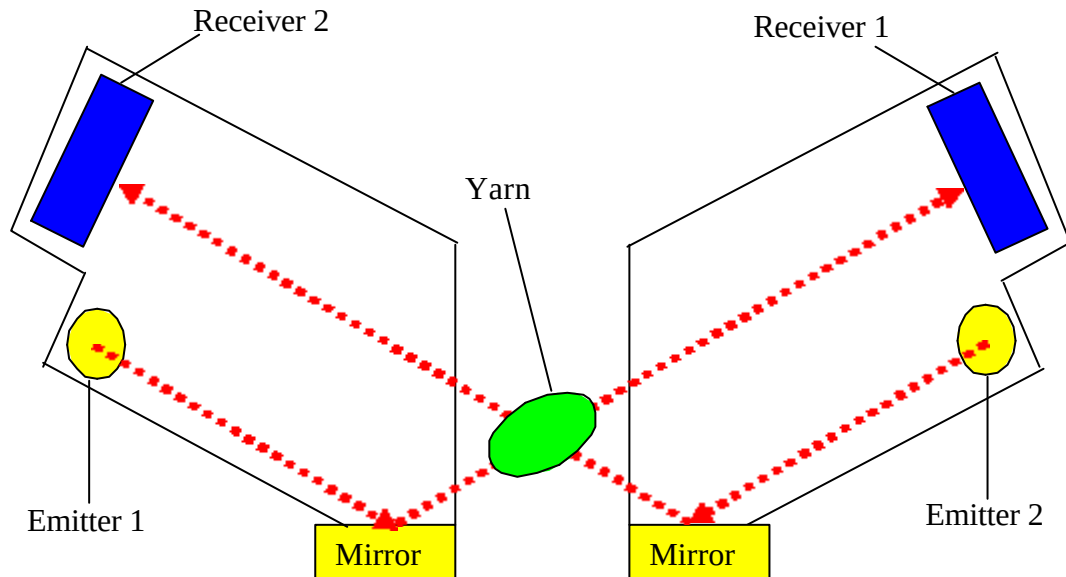


Figure 5.8. Two-dimensional measuring principle

5.2.1.3. Measuring principle of sensors

Independent of the used measuring principle, the evaluation is performed on the basis of the relative yarn signal change in contrast to the base value. The base value corresponds to the mean diameter of the measured yarn (Figure 5.9).

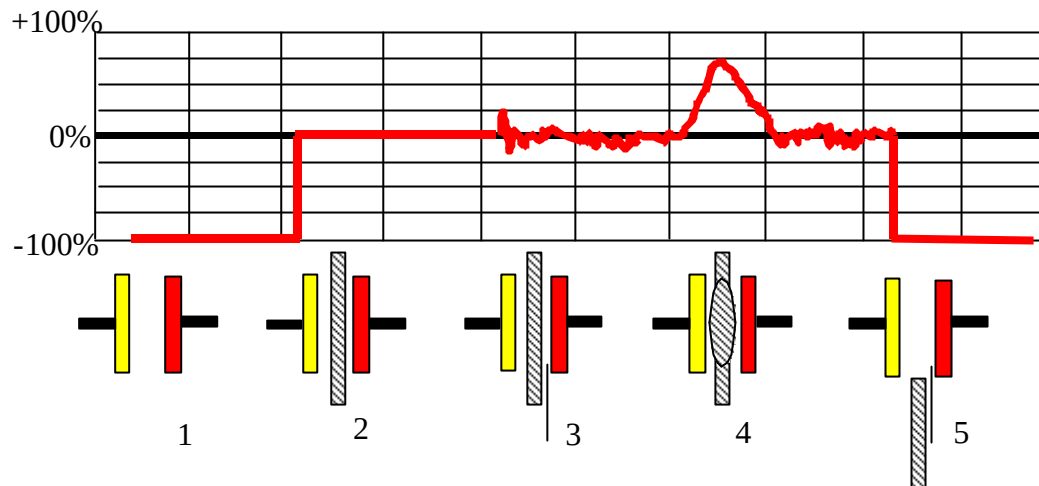


Figure 5.9. Measuring principle of a sensor

The detailed explanation of above figures is given below;

1. No yarn in the measuring field. In this state, the yarn signal is defined as -100%.
2. A yarn of certain diameter is inserted into the measuring field. The yarn signal changes from -100% to 0%. The change of 100% corresponds to the yarn diameter.
3. The yarn is moved in the measuring field. The yarn signal corresponds to the yarn variations. The mean value of the variation is defined as 0 %. 0 % is the base value for the deviations of a positive thick place and a negative thin place.
4. Thick place in the measuring field. The deviation is measured in percentage to the base value. In the above figure, the deviation is +60%.
5. As soon as the yarn leaves the measuring field, the yarn signal drops to -100%. [23]

The definitions are valid for both measuring principles. The change in percent refers to the mass in case of the capacitive measuring principle and the diameter in the case of the optical measuring principle.

5.2.1.4. Sensor in use

The sensor is working with infrared light and analog output type optical fiber photoelectric sensor, which is produced by Nais Company. This sensor has two probes (receiver and emitter). This photoelectric sensor took the results. Some properties of these sensors are given in Table 5.1. One millisecond or fewer switches were set for the response time of the sensor during all the tests.

Table 5.1. Properties of the sensor

Item	Specifications
Supply voltage	12 to 24 V DC $\pm$ 10% Ripple P-P 10% or less
Current consumption	35 mA or less
Output voltage	1 to 5V (proportional to incident beam)
Output current	5mA or less
Load resistance	2k Ω or more
Response time	Switchable either 1 ms or less or 10 ms or less
Sensitivity adjuster	8-turn adjuster with the pointer
Weight	Approx.60 g

Figure 5.10 and 5.11 shows the sensors used in this study.

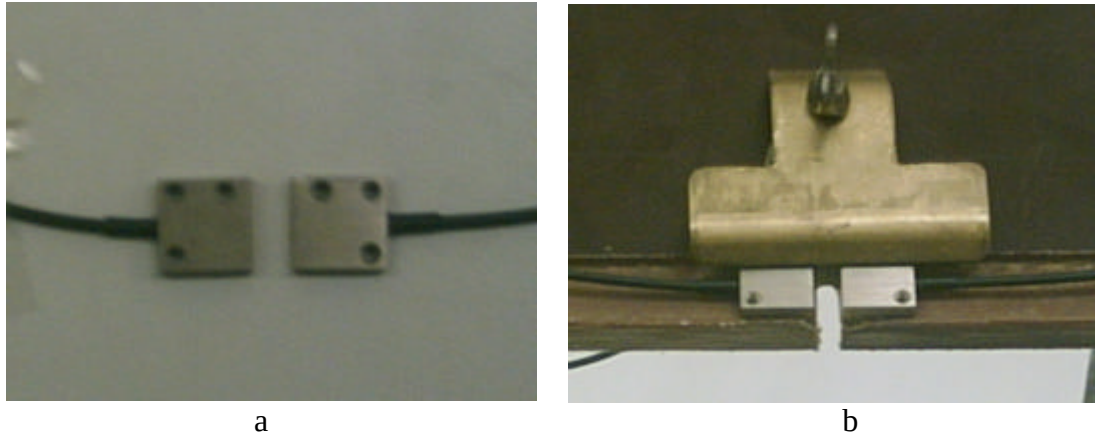


Figure 5.10. (a-b) Sensor in use

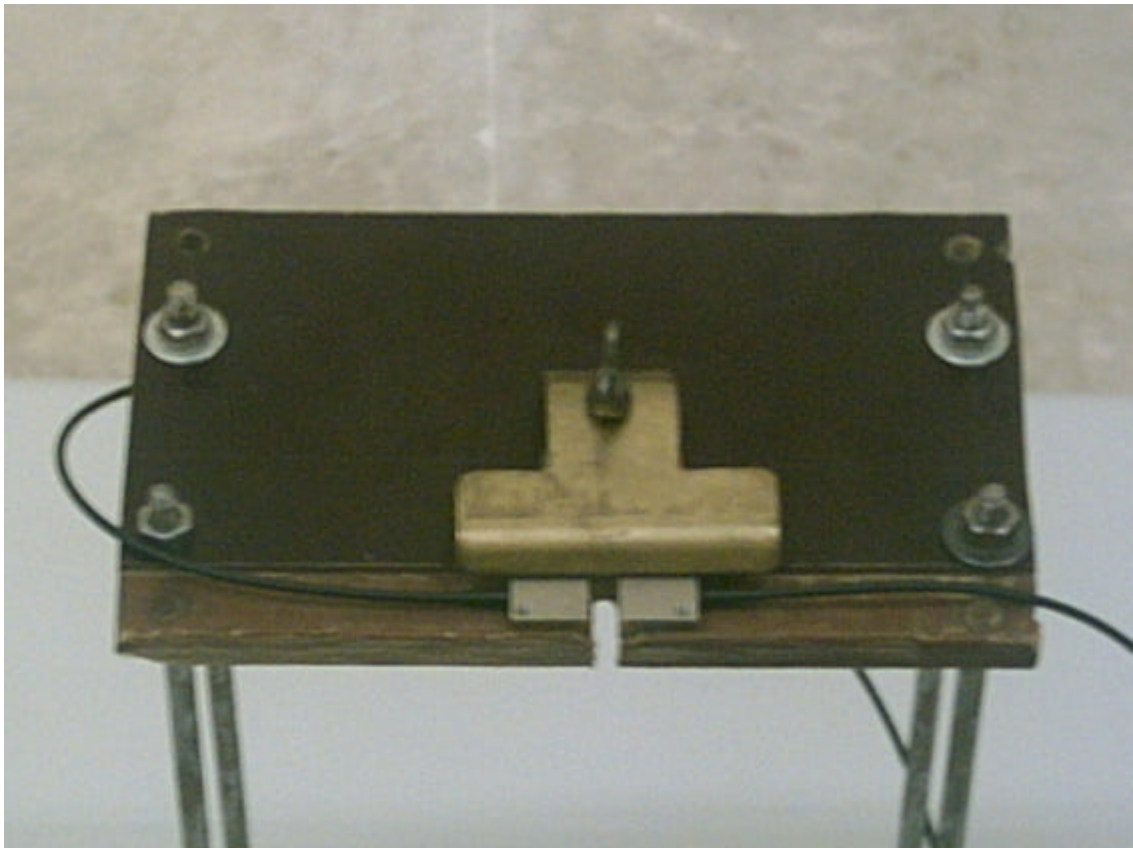


Figure 5.11. Sensor in uses

5.2.1.5. Calibration of fiber optic sensors

An equation to convert the electrical signal differences into diameter of the measured yarns was obtained experimentally by measuring the values of the electrical signal difference of sensor with respect to known yarn diameters in millimeter. Table 5.2 shows diameter values versus signal difference of sensors.

Table 5.2. Diameter versus signal difference of sensor

No	App. diameter (mm)	Measured Electrical Signal Difference (Volt)
1	2	1,626
2	1	0,8
3	0,5	0,312
4	0,342	0,256
5	0,306	0,233
6	0,216	0,152
7	0,177	0,114
8	0,137	0,067

Figure 5.12 shows the calibration curve obtained by using the values Table 5.2.

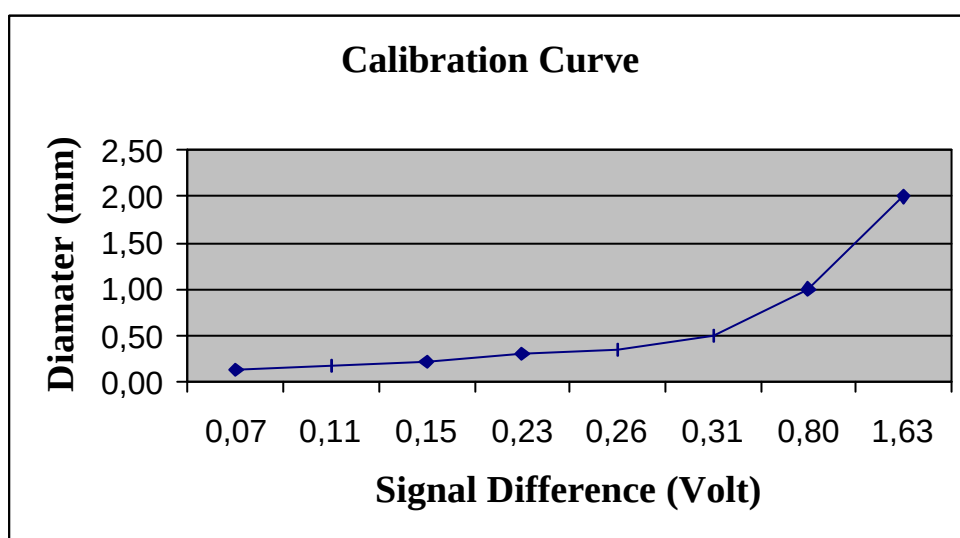


Figure 5.12. Calibration curve

By using these points a second order equation was obtained that, satisfy the above curve.

$$y = -1.728478 * 10^{-2} * x^2 + 1.228327 * x + 0.04579659 \dots\dots\dots (5.1)$$

Where y and x are the diameter of the material in millimeter and signal difference of the sensor in volt respectively. The equation (5.1) was used to convert the voltage values into the thickness values.

5.2.2 The table (Sensor stand)

The table that holds the sensors was manufactured at the Workshop of the Mechanical Engineering Department. The table has dimensions of 110x175 mm and 10 mm in thickness made of wooden as shown in Figure 5.13. The probes of sensor were placed on the rail of the table. After adjusting the optimal distance between sensor probes, the probes were fixed by the clamp.

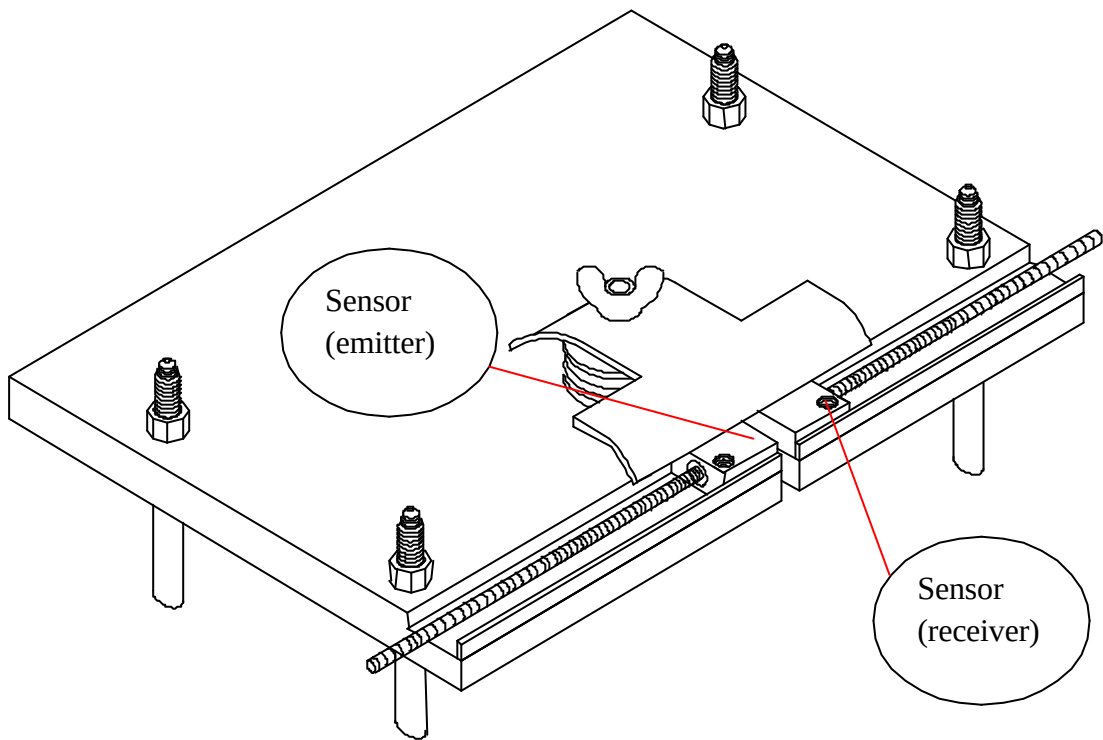


Figure 5.13. The table (Sensor stand)

5.2.3. AD-DA converter

The sensor, which is used, for measuring the yarn evenness is an analog output type. However, the results must be converted into digital output because of evaluation in computer. For this translation, from analog to digital, a converter card, which is produced by Decision Computer Systems Company, is used. 12 bits A/D-D/A card is a high precision data conversion system for PC/XT, PC/AT, or compatible computer. It contains one 12 bits digital to analog channel and sixteen 12 bits analog to digital

channels. The test program, which is necessary for card to perception the signal, is written in matlab program. Some information about card is given below [23];

- a) Provides 16 A/D channels and the resolution is 12 bits.
- b) Unipolar or bipolar selectable.
- c) Input voltage range from 0 V to 9 V for unipolar, and from -9 V to 9 V for bipolar.
- d) I/O port address selectable.
- e) Nonlinearity 0.2%.
- f) Successive approximation method.
- g) Current setting time 0.712 millisecond.
- h) Conversion time 60 μ sec (each channel for A/D).

5.3. Experimental Results

Experimental results were obtained from a ring spun cotton yarn in different linear densities such as 10, 20, 30, in English yarn count (Ne) system. The voltage signals were converted into the diameter of yarns in mm by using the equation 5.1 derived from calibration curve. The parameters of the set-up and software were set the following values:

- a) Trigger speed of the A/D converter: 1 millisecond/data
- b) Fiber type: short staple
- c) Fiber fineness unit: microgram/inch
- d) Test speed unit: m/min
- e) Count unit: Ne
- f) Material type: 100% cotton
- g) Yarn type: ring spun
- h) Testing speed: 25 m/min
- i) Test duration: 5 min
- j) Long thick and thin place setting: 5 cm
- k) Mass diagram cut length setting: normal (1 cm)
- l) Number of stored data for each specimen: 300000
- m) Interval between two successive points: 0.5 mm

5.3.1. Experimental results of Ne 10 –yarn

The first test was performed for the linear density of Ne 10, 100% cotton, short staple and ring-spun yarn. The length of long faults was selected 5 centimeters. Test speed was selected 25 m/min. Totally 300.000 data was obtained and saved to the memory of the personal computer at the end of the five-minutes test duration. All numerical quality parameters available on the software were calculated by using these 300.000 data. The same test parameters are also valid for experimentally determined quality results of Ne 20 and Ne 30 yarn samples. The printout of experimentally determined numerical quality results of Ne 10 yarn is shown in Figure 5.14.

UNIVERSITY OF GAZIANTEP TABULATED RESULTS			
Factory Name : Sanko	Operator : ERDEM	Staple Length : Short staple	
Yarn Type : Ring Spun	Test Date : 23.12.2004	Fibre 1 Fineness : 4 microgram/inch	
Test Number : 2	Test Time : 11:54:04	Fibre 1 Proportion : 100 %	
Count : 10 Nec	Test Speed : 25 m/min	Fibre 2 Fineness : 0 microgram/inch	
Material Type : 100% Cotton	Test Duration : 5 min	Fibre 2 Proportion : 0 %	
Comments : Ne 10			
NUMERICAL RESULTS			
Test Number	1		
U _m %	8,15		
CV _m %	10,19		
CV _m (1m)%	2,05		
CV _m (3m)%	1,35		
CV _m (10m)%	0,97		
CV _m (50m)%	0,00		
CV _m (100m)%	0,00		
Thin (-30%)	0		
Thin (-40%)	0		
Thin (-50%)	0		
Thin (-60%)	0		
Thick (+35%)	8		
Thick (+50%)	0		
Thick (+70%)	0		
Thick (+100%)	0		
Neps (+140%)	200		
Neps (+200%)	40		
Neps (+280%)	8		
Neps (+400%)	0		
LONG FAULTS (Length Of Long Faults:5cm)			
Test Number	1		
-30%	0		
-40%	0		
-50%	0		
-60%	0		
+35%	0		
+50%	0		
+70%	0		
+100%	0		

Figure 5.14. Experimentally determined numerical results of Ne 10-yarn

The printout of numerical results of Ne 10 yarn measured on Uster Tester 4 is shown in Figure 5.15.

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BULUT TEKSTİL GAZİANTEP / TURKEY

Style BOBIN Sample ID 02676 Nom. count Nec 10 Nom. twist
Tests 1 / 1 v= 25 m/min t= 5 min Meas. slot 3 Short staple

Extended Table M+H

Article Material class Yarn Mach. Nr.

Ne 10 25m/dak 5 dakika

Nr	U%	CVm	CVm 1m	CVm 3m	CVm 10m	DR 1.5m 5%	Rel. Cnt ±	H	sh	sh 1m	sh 3m
	%	%	%	%	%	%	%				
1	9.46	12.07	5.08	4.41		31.5	0.0	8.80	1.96	0.40	0.25
Mean	9.46	12.07	5.08	4.41		31.5	0.0	8.80	1.96	0.40	0.25
CV											
s											
Q95											
Max	9.46	12.07	5.08	4.41		31.5	0.0	8.80	1.96	0.40	0.25
Min	9.46	12.07	5.08	4.41		31.5	0.0	8.80	1.96	0.40	0.25

Nr	Thin -30%	Thin -40%	Thin -50%	Thin -60%	Thick +35%	Thick +50%	Thick +70%	Thick +100%	Neps +140%	Neps +200%	Neps +280%	Neps +400%
	/km	/km	/km	/km	/km	/km	/km	/km	/km	/km	/km	/km
1	496.0	0.0	0.0	0.0	224.0	72.0	56.0	56.0	232.0	64.0	64.0	40.0
Mean	496.0	0.0	0.0	0.0	224.0	72.0	56.0	56.0	232.0	64.0	64.0	40.0
CV												
s												
Q95												
Max	496.0	0.0	0.0	0.0	224.0	72.0	56.0	56.0	232.0	64.0	64.0	40.0
Min	496.0	0.0	0.0	0.0	224.0	72.0	56.0	56.0	232.0	64.0	64.0	40.0

Figure 5.15. Numerical results taken from Uster Tester 4 of Ne 10-yarn

The printout of numerical results of Ne 10 yarn measured on Premier Tester 7000 is shown in Figure 5.16.

Premier Tester 7000 V3.0.4

UNIVERSITY OF GAZIANTEP

8/10/04 4:43:51 PM PgNo. 1

SINGLE/OVERALL RESULTS

Article Number:1

Department :Ring Frame

Test Duration :5 min

Count :10 Nec

Material :PAMUK

Machine Number:1

Comments :25 M/DAK 5 DAKIKA

Operator :ERDEM

Test Number :2

Test Date :8/10/04

Test Speed :25 m/min

Test Time :2:22:33 PM

Fib Type :Short Staple

Fib1 Value:3.51 µg/inch

Fib1 Prop :100%

Test No.	Um (%)	CVm (%)	Index (-)	Thn/Km (-30%)	Thn/Km (-40%)	Thn/Km (-50%)	Thn/Km (-60%)	Thk/Km (+35%)
1	9.22	11.71	2.42	464	0	0	0	160
Mean	9.22	11.71	2.42	464	0	0	0	160

Test No.	Thk/Km (+50%)	Thk/Km (+70%)	Thk/Km (+100%)	Neps/Km (+140%)	Neps/Km (+200%)	Neps/Km (+280%)	Neps/Km (+400%)	Rel.Cnt (%)
1	0	0	0	152	16	0	0	100.00
Mean	0	0	0	152	16	0	0	100.00

Test No.	m (max,1m) (%)	m (min,1m) (%)	m (max,H1m) (%)	m (min,H1m) (%)
1	14.80	-10.70	18.90	-12.90
Mean	14.80	-10.70	18.90	-12.90

Figure 5.16. Numerical results taken from Premier Tester 7000 of Ne 10-yarn

Mass diagrams were drawn according to 1 cm cut length in all yarn measurements. Mass diagrams of Ne 10-yarn drawn by experimental set-up, Uster Tester 4 and Premier Tester 7000 are shown in Figure 5.17, Figure 5.18 and Figure 5.19 respectively. The test length of mass diagram drawn by Uster Tester 4 was 400 meter. Because of extended horizontal axis of mass diagram drawn by Premier Tester 7000, the 20 meters-length of this diagram was shown in Figure 5.19. The full length of this diagram 125 meters.

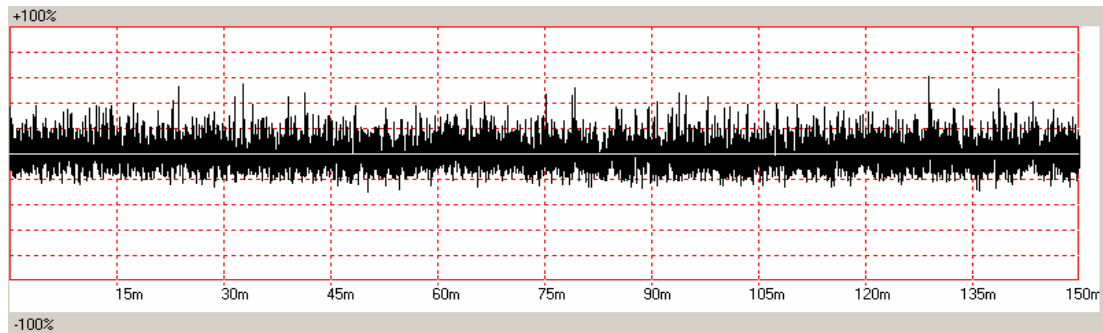


Figure 5.17. Experimentally determined diameter diagram of Ne 10-yarn

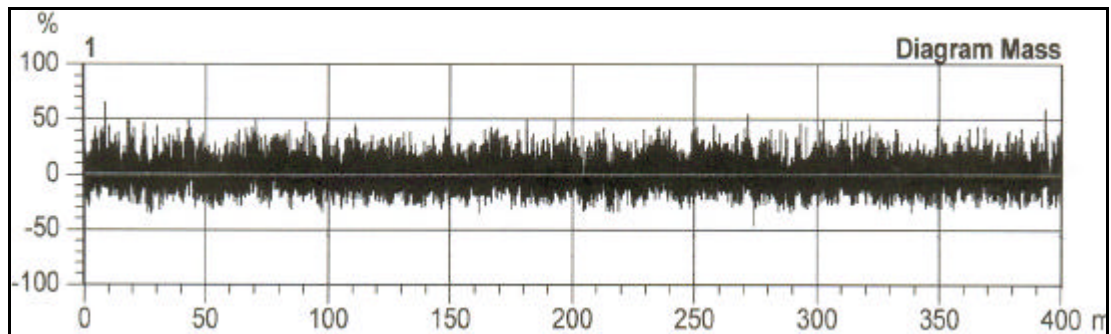


Figure 5.18. Mass diagram taken from Uster Tester 4 of Ne 10-yarn

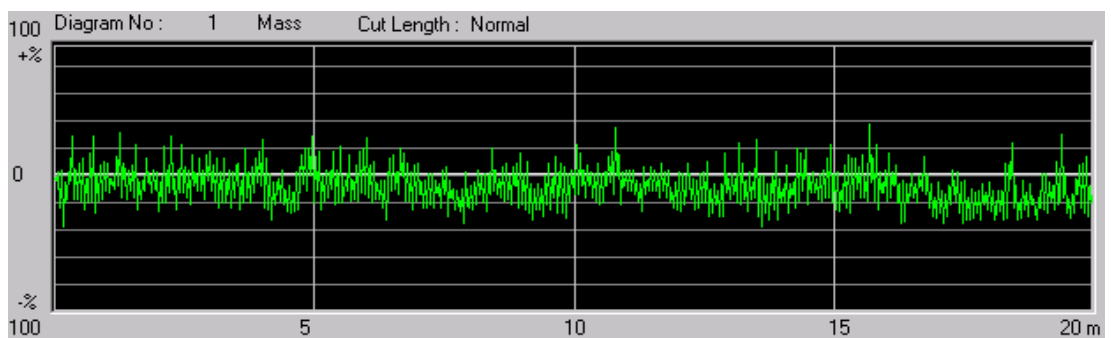


Figure 5.19. Mass diagram taken from Premier Tester 7000 of Ne 10-yarn

There are no special test parameters in drawing the spectrogram. The spectrograms of Ne 10-yarn drawn by experimental set-up, Uster Tester 4 and Premier Tester 7000 are shown in Figure 5.20, Figure 5.21 and Figure 5.22 respectively.

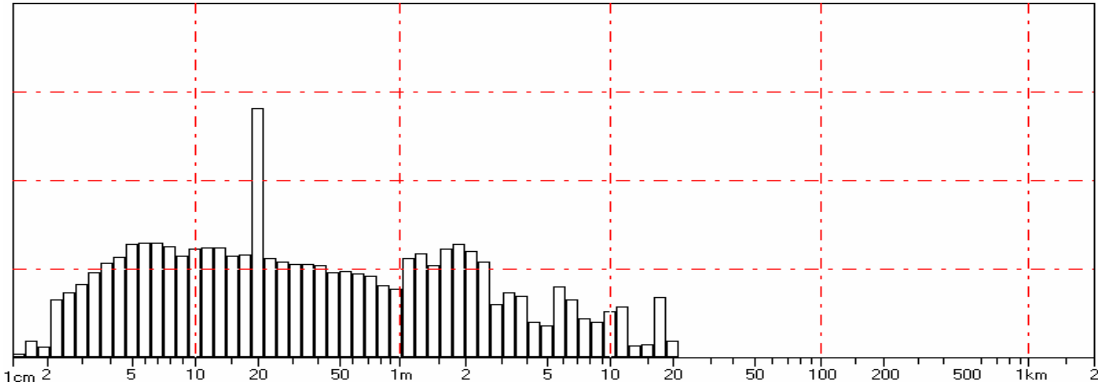


Figure 5.20 Experimentally determined diameter spectrogram of Ne 10-yarn

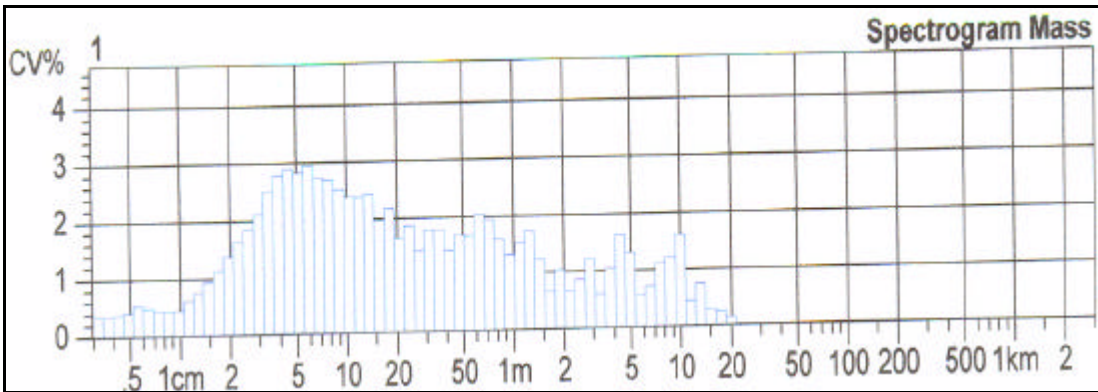


Figure 5.21. Mass spectrogram taken from Uster Tester 4 of Ne 10-yarn

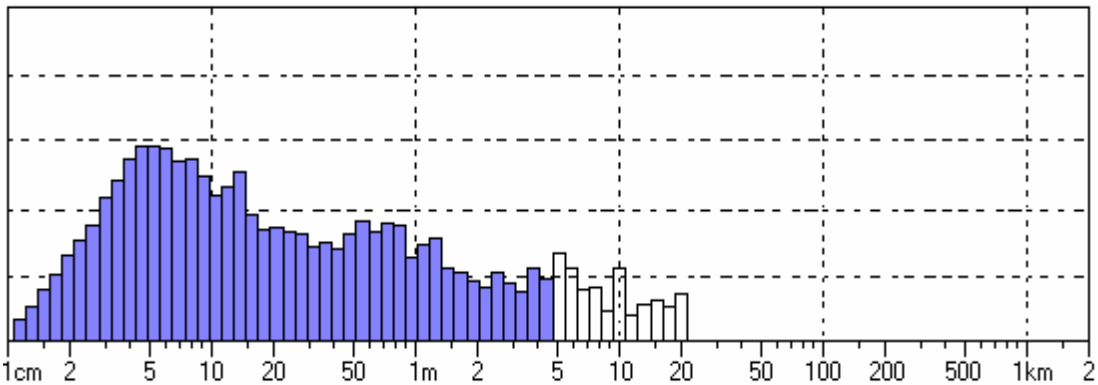


Figure 5.22. Mass spectrogram taken from Premier Tester 7000 of Ne 10-yarn

There are no special test parameters in drawing the histogram. The histograms of Ne 10 yarn drawn by experimental set-up and Premier Tester 7000 are shown in Figure 5.23 and Figure 5.24 respectively. There was not histogram option in Uster Tester 4.

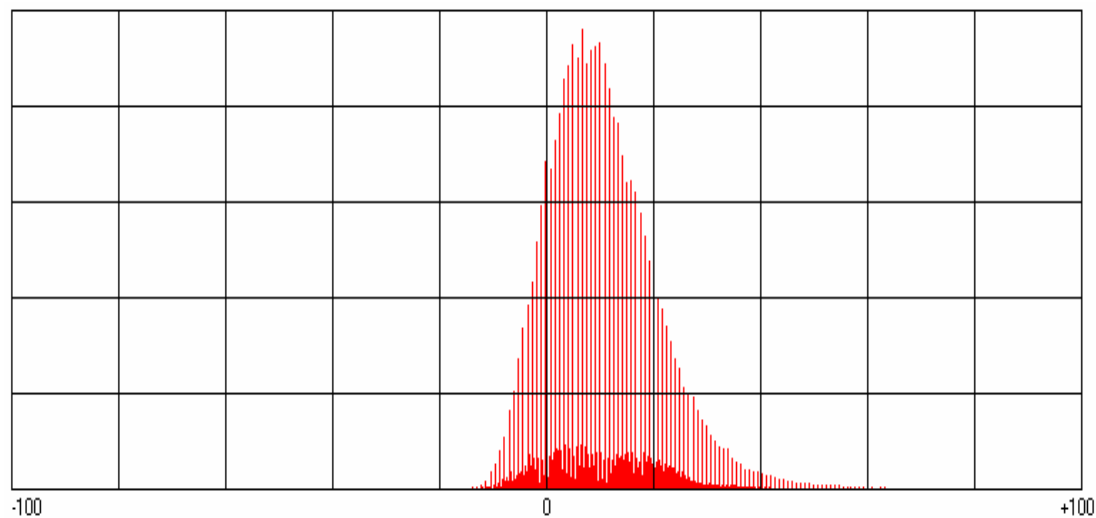


Figure 5.23. Experimentally determined diameter histogram of Ne 10-yarn

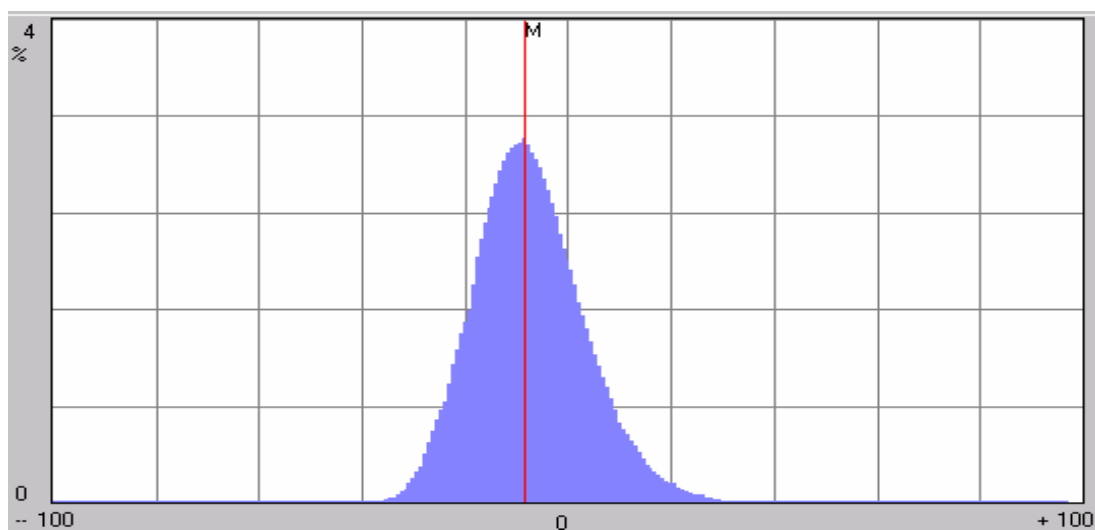


Figure 5.24. Mass histogram taken from Premier Tester 7000 of Ne 10-yarn

5.3.2. Experimental results of Ne 20 –yarn

The printout of experimentally determined numerical quality results of Ne 20 yarn is shown in Figure 5.25.

UNIVERSITY OF GAZIANTEP TABULATED RESULTS			
Factory Name	: Sanko	Operator	: ERDEM
Yarn Type	: Ring Spun	Test Date	: 23.12.2004
Test Number	: 3	Test Time	: 11:57:49
Count	: 20 Nec	Test Speed	: 25 m/min
Material Type	: 100% Cotton	Test Duration	: 5 min
Comments	: Ne 20		
		Staple Length	: Short staple
		Fibre 1 Fineness	: 3,5 microgram/inch
		Fibre 1 Proportion	: 100 %
		Fibre 2 Fineness	: 0 microgram/inch
		Fibre 2 Proportion	: 0 %
NUMERICAL RESULTS			
Test Number	1		
U _m %	9,66		
CV _m %	12,07		
CV _m (1m)%	2,32		
CV _m (3m)%	1,49		
CV _m (10m)%	0,60		
CV _m (50m)%	0,00		
CV _m (100m)%	0,00		
Thin (-30%)	0		
Thin (-40%)	0		
Thin (-50%)	0		
Thin (-60%)	0		
Thick (+35%)	24		
Thick (+50%)	8		
Thick (+70%)	8		
Thick (+100%)	0		
Neps (+140%)	488		
Neps (+200%)	160		
Neps (+280%)	56		
Neps (+400%)	24		
LONG FAULTS (Length Of Long Faults:5cm)			
Test Number	1		
-30%	0		
-40%	0		
-50%	0		
-60%	0		
+35%	8		
+50%	8		
+70%	0		
+100%	0		

Figure 5.25. Experimentally determined numerical results of Ne 20-yarn

The printout of numerical results of Ne 20 yarn measured on Uster Tester 4 is shown in Figure 5.26.

USTER TESTER 4 - SE R 1.7 Sat 09.10.04 11:19 Operator ERDEM Page

BULUT TEKSTİL GAZİANTEP / TURKEY

Style BOBIN Sample ID 02677 Nom. count Nec 20 Nom. twist
Tests 1 / 1 v= 25 m/min t= 5 min Meas. slot 3 Short staple

Extended Table M+H

Article Material class Yarn Mach. Nr.

Ne 20 25m/dak 5 dakika

Nr	U%	CVm	CVm 1m	CVm 3m	CVm 10m	DR 1.5m 5%	Rel. Cnt ±	H	sh	sh 1m	sh 3m
	%	%	%	%	%	%	%				
1	10.57	13.43	3.73	2.73		8.7	0.0	7.86	1.97	0.44	0.22
Mean	10.57	13.43	3.73	2.73		8.7	0.0	7.86	1.97	0.44	0.22
CVs											
Q95											
Max	10.57	13.43	3.73	2.73		8.7	0.0	7.86	1.97	0.44	0.22
Min	10.57	13.43	3.73	2.73		8.7	0.0	7.86	1.97	0.44	0.22

Nr	Thin -30%	Thin -40%	Thin -50%	Thin -60%	Thick +35%	Thick +50%	Thick +70%	Thick +100%	Neps +140%	Neps +200%	Neps +280%	Neps +400%
	/km	/km	/km	/km	/km	/km	/km	/km	/km	/km	/km	/km
1	1456	80.0	0.0	0.0	512.0	96.0	8.0	0.0	624.0	64.0	16.0	0.0
Mean	1456	80.0	0.0	0.0	512.0	96.0	8.0	0.0	624.0	64.0	16.0	0.0
CVs												
Q95												
Max	1456	80.0	0.0	0.0	512.0	96.0	8.0	0.0	624.0	64.0	16.0	0.0
Min	1456	80.0	0.0	0.0	512.0	96.0	8.0	0.0	624.0	64.0	16.0	0.0

Figure 5.26. Numerical results taken from Uster Tester 4 of Ne 20-yarn

The printout of numerical results of Ne 20 yarn measured on Premier Tester 7000 is shown in Figure 5.27.

Premier Tester 7000 V3.0.4

UNIVERSITY OF GAZIANTEP

8/10/04 4:59:22 PM PgNo. 1

SINGLE/OVERALL RESULTS

Article Number:1Operator :ERDEM Fib Type :Short Staple

Department :Ring FrameTest Number :3 Fib1 Value:3.51 µg/inch

Test Duration :5 minTest Date :8/10/04 Fib1 Prop :100%

Count :20 NecTest Speed :25 m/min

Material :PAMUKTest Time :2:32:44 PM

Machine Number:1

Comments :25 M/DAK 5 DAKIKA

Test No.	Um (%)	CVm (%)	Index (-)	Thn/Km (-30%)	Thn/Km (-40%)	Thn/Km (-50%)	Thn/Km (-60%)	Thk/Km (+35%)
1	10.47	13.29	1.94	1288	56	0	0	440
Mean	10.47	13.29	1.94	1288	56	0	0	440

Test No.	Thk/Km (+50%)	Thk/Km (+70%)	Thk/Km (+100%)	Neps/Km (+140%)	Neps/Km (+200%)	Neps/Km (+280%)	Neps/Km (+400%)	Rel.Cnt (%)
1	72	16	0	672	104	16	8	100.00
Mean	72	16	0	672	104	16	8	100.00

Test No.	m (max, 1m) (%)	m (min, 1m) (%)	m (max, H1m) (%)	m (min, H1m) (%)
1	11.20	-11.50	15.30	-13.70

Figure 5.27. Numerical results taken from Premier Tester 7000 of Ne 20-yarn

Mass diagrams were drawn according to 1 cm cut length in all yarn measurements. Mass diagrams of Ne 20-yarn drawn by experimental set-up, Uster Tester 4 and Premier Tester 7000 are show in Figure 5.28, 5.29 and 5.30 respectively. The test length of mass diagram drawn by Uster Tester 4 was 150 meter. Because of extended horizontal axis of mass diagram drawn by Premier Tester 7000, the 20 meters-length of this diagram was shown in Figure 5.30. The full length of this diagram 125 meters.

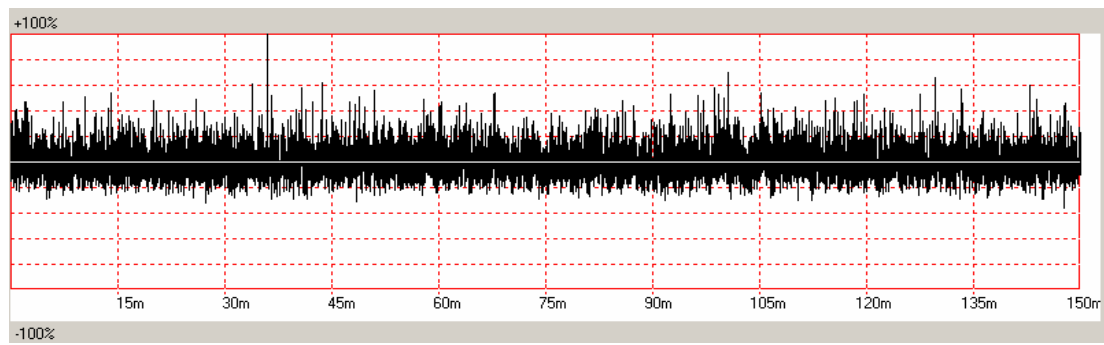


Figure 5.28. Experimentally determined diameter diagram of Ne 20-yarn

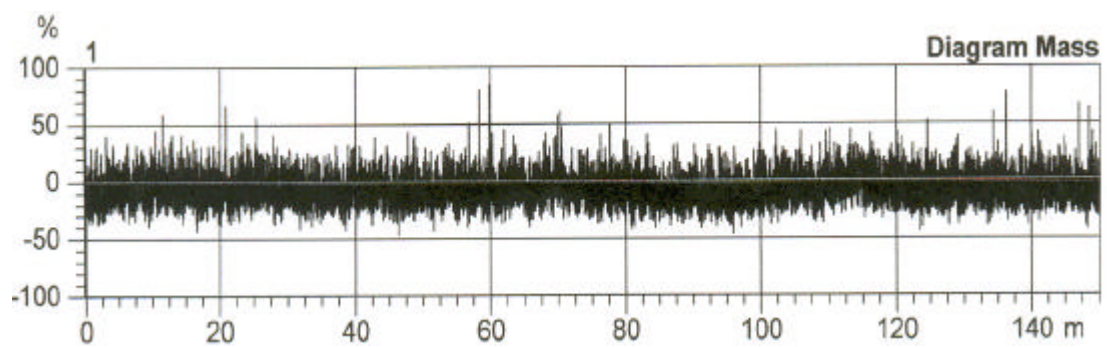


Figure 5.29. Mass diagram taken from Uster Tester 4 of Ne 20-yarn

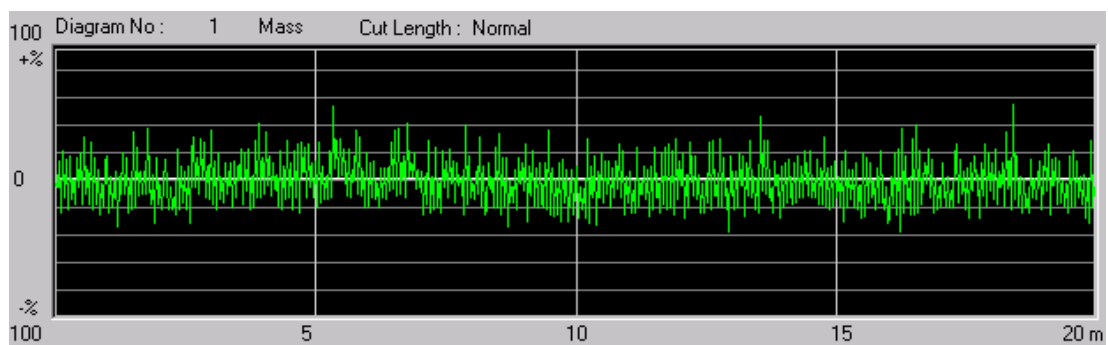


Figure 5.30. Mass diagram taken from Premier Tester 7000 of Ne 20-yarn

The spectrograms of Ne 20-yarn drawn by experimental set-up, Uster Tester 4 and Premier Tester 7000 are shown in Figure 5.31, 5.32 and 5.33 respectively.

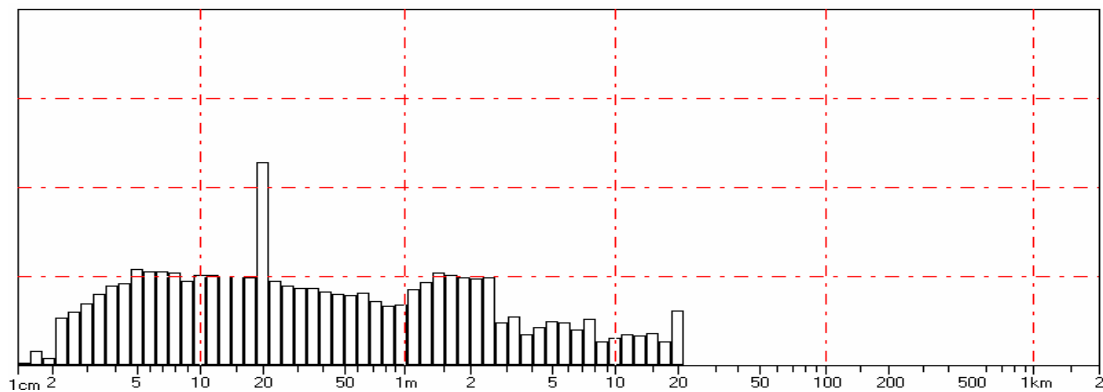


Figure 5.31. Experimentally determined diameter spectrogram of Ne 20-yarn

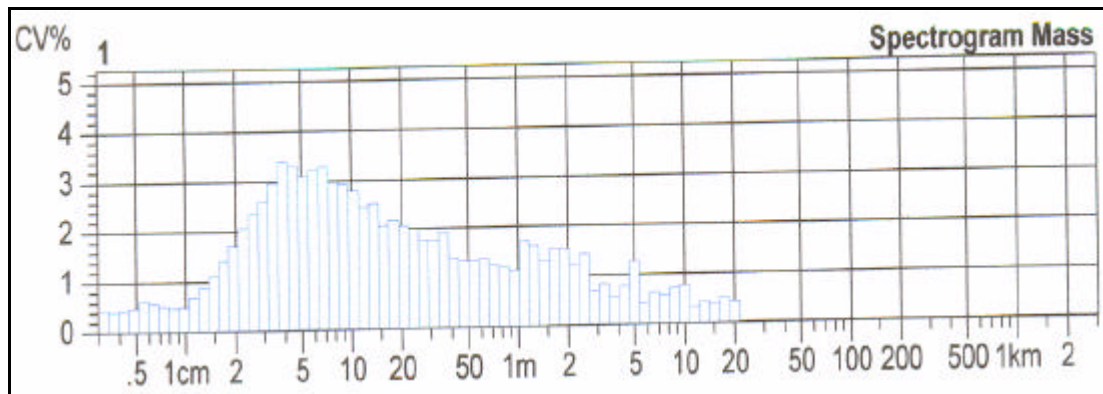


Figure 5.32. Mass spectrogram taken from Uster Tester 4 of Ne 20-yarn

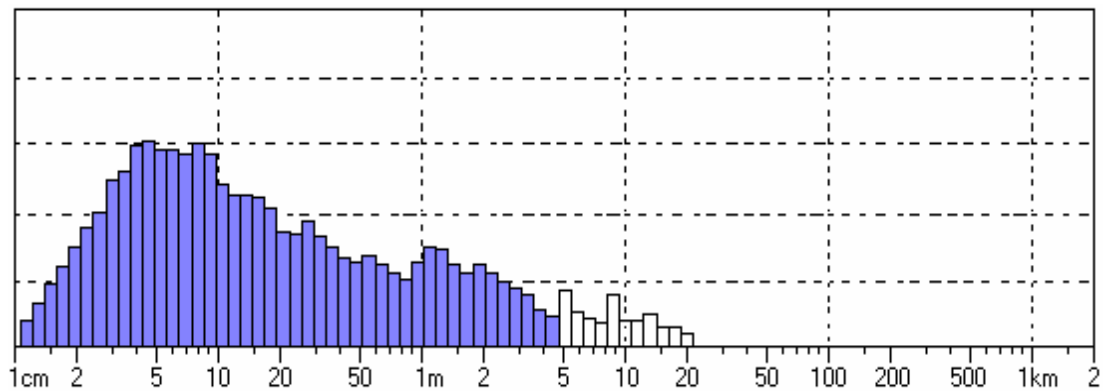


Figure 5.33. Mass spectrogram taken from Premier Tester 7000 of Ne 20-yarn

The histograms of Ne 20 yarn drawn by experimental set-up and Premier Tester 7000 are shown in Figure 5.34 and 5.35 respectively. There was not histogram option in Uster Tester 4.

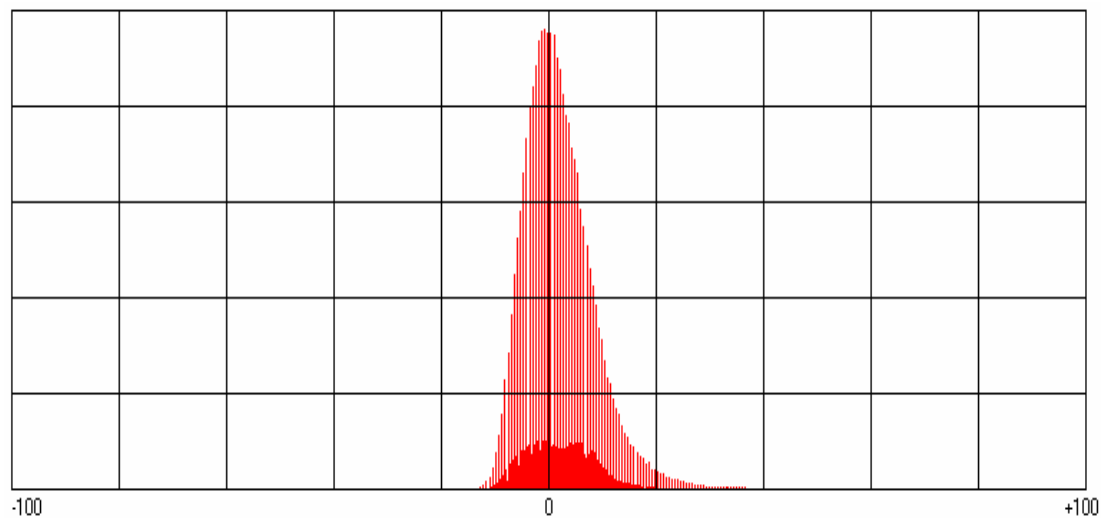


Figure 5.34. Experimentally determined diameter histogram of Ne 20-yarn

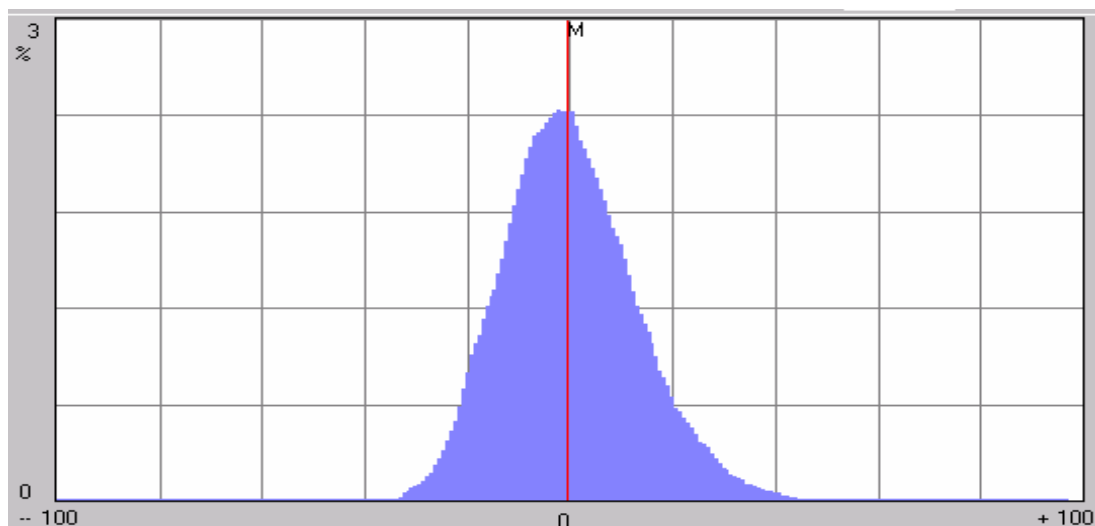


Figure 5.35. Mass histogram taken from Premier Tester 7000 of Ne 20-yarn

5.3.3. Experimental results of Ne 30 –yarn

The printout of experimentally determined numerical quality results of Ne 30 yarn is shown in Figure 5.36.

UNIVERSITY OF GAZİANTEP TABULATED RESULTS			
Factory Name : Selçuk İplik	Operator : ERDEM	Staple Length : Short staple	
Yarn Type : Ring Spun	Test Date : 23.12.2004	Fibre 1 Fineness : 3,5 microgram/inch	
Test Number : 4	Test Time : 12:01:34	Fibre 1 Proportion : 100 %	
Count : 30 Nec	Test Speed : 25 m/min	Fibre 2 Fineness : 0 microgram/inch	
Material Type : 100% Cotton	Test Duration : 5 min	Fibre 2 Proportion : 0 %	
Comments : Ne 30			
NUMERICAL RESULTS			
Test Number	1		
U _m %	10,58		
CV _m %	13,23		
CV _m (1m)%	3,72		
CV _m (3m)%	3,18		
CV _m (10m)%	3,04		
CV _m (50m)%	0,00		
CV _m (100m)%	0,00		
Thin (-30%)	8		
Thin (-40%)	0		
Thin (-50%)	0		
Thin (-60%)	0		
Thick (+35%)	64		
Thick (+50%)	8		
Thick (+70%)	0		
Thick (+100%)	0		
Neps (+140%)	736		
Neps (+200%)	176		
Neps (+280%)	48		
Neps (+400%)	0		
LONG FAULTS (Length Of Long Faults:5cm)			
Test Number	1		
-30%	0		
-40%	0		
-50%	0		
-60%	0		
+35%	0		
+50%	0		
+70%	0		
+100%	0		

Figure 5.36. Experimentally determined numerical results of Ne 30-yarn

The printout of numerical results of Ne 30 yarn measured on Uster Tester 4 is shown in Figure 5.37.

USTER TESTER 4 - SE R 1.7

Sat 09.10.04 11:26

Operator ERDEM

Page

BULUT TEKSTİL

GAZİANTEP / TURKEY

Style BOBIN

Sample ID 02678

Nom. count Nec 30

Nom. twist Short staple

Tests 1 / 1

v= 25 m/min

t= 5 min

Meas. slot 4

Extended Table M+H

Article

Material class

Yarn

Mach. Nr.

Ne 30 25m/dak 5 dakika

Nr	U%	CVm	CVm 1m	CVm 3m	CVm 10m	DR 1.5m 5% %	Rel. Cnt ± %	H	sh	sh 1m	sh 3m
1	11.98	15.19	4.83	4.11		25.9	0.0	6.26	1.72	0.24	0.12
Mean	11.98	15.19	4.83	4.11		25.9	0.0	6.26	1.72	0.24	0.12
CV											
s											
Q95											
Max	11.98	15.19	4.83	4.11		25.9	0.0	6.26	1.72	0.24	0.12
Min	11.98	15.19	4.83	4.11		25.9	0.0	6.26	1.72	0.24	0.12

Nr	Thin -30%	Thin -40%	Thin -50%	Thin -60%	Thick +35%	Thick +50%	Thick +70%	Thick +100%	Neps +140%	Neps +200%	Neps +280%	Neps +400%
	/km	/km	/km	/km	/km	/km	/km	/km	/km	/km	/km	/km
1	2776	240.0	8.0	0.0	1032	152.0	24.0	0.0	1664	264.0	48.0	0.0
Mean	2776	240.0	8.0	0.0	1032	152.0	24.0	0.0	1664	264.0	48.0	0.0
CV												
s												
Q95												
Max	2776	240.0	8.0	0.0	1032	152.0	24.0	0.0	1664	264.0	48.0	0.0
Min	2776	240.0	8.0	0.0	1032	152.0	24.0	0.0	1664	264.0	48.0	0.0

Figure 5.37. Numerical results taken from Uster Tester 4 of Ne 30-yarn

The printout of numerical results of Ne 20 yarn measured on Premier Tester 7000 is shown in Figure 5.38.

Premier Tester 7000 V3.0.4

UNIVERSITY OF GAZIANTEP

8/10/04 5:20:29 PM PgNo. 1

SINGLE/OVERALL RESULTS

Article Number:1

Department :Ring Frame

Test Duration :5 min

Count :30 Nec

Material :PAMUK

Machine Number:1

Comments :25 M/DAK 5 DAKIKA

Operator :ERDEM

Test Number :4

Test Date :8/10/04

Test Speed :25 m/min

Test Time :2:42:52 PM

Fib Type :Short Staple

Fib1 Value:3.51 µg/inch

Fib1 Prop :100%

Test No.	Um (%)	CVm (%)	Index (-)	Thn/Km (-30%)	Thn/Km (-40%)	Thn/Km (-50%)	Thn/Km (-60%)	Thk/Km (+35%)
1	12.09	15.35	1.83	2296	248	8	0	912
Mean	12.09	15.35	1.83	2296	248	8	0	912

Test No.	Thk/Km (+50%)	Thk/Km (+70%)	Thk/Km (+100%)	Neps/Km (+140%)	Neps/Km (+200%)	Neps/Km (+280%)	Neps/Km (+400%)	Rel.Cnt (%)
1	88	16	0	1736	344	8	0	100.00
Mean	88	16	0	1736	344	8	0	100.00

Test No.	m (max,1m) (%)	m (min,1m) (%)	m (max,H1m) (%)	m (min,H1m) (%)
1	17.10	-16.10	18.80	-18.40
Mean	17.10	-16.10	18.80	-18.40

Figure 5.38. Numerical results taken from Premier Tester 7000 of Ne 30-yarn

Mass diagrams were drawn according to 1 cm cut length in all yarn measurements. Mass diagrams of Ne 30-yarn drawn by experimental set-up, Uster Tester 4 and Premier Tester 7000 are shown in Figure 5.39, 5.40 and 5.41 respectively. The test length of mass diagram drawn by Uster Tester 4 was 125 meter. Because of extended horizontal axis of mass diagram drawn by Premier Tester 7000, the 20 meters-length of this diagram was shown in Figure 5.41. The full length of this diagram 125 meters.

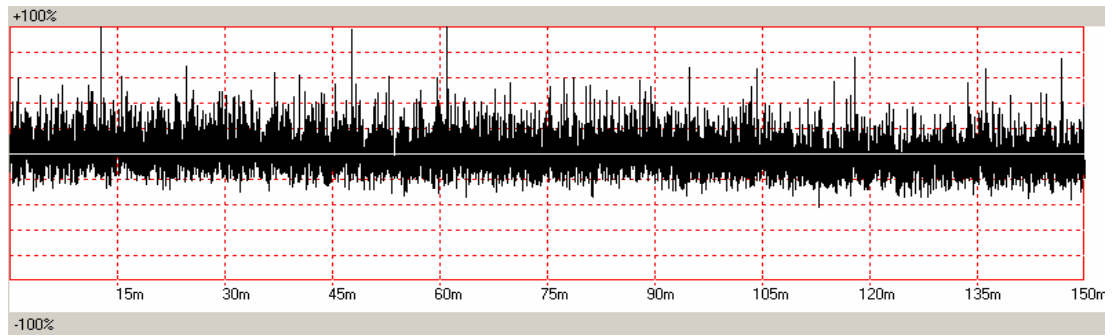


Figure 5.39. Experimentally determined diameter diagram of Ne 30-yarn

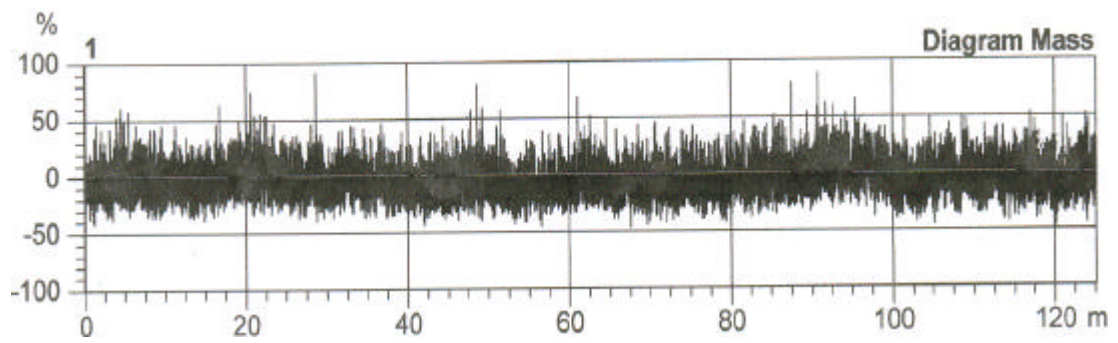


Figure 5.40. Mass diagram taken from Uster Tester 4 of Ne 30-yarn



Figure 5.41. Mass diagram taken from Premier Tester 7000 of Ne 30-yarn

The spectrograms of Ne 30-yarn drawn by experimental set-up, Uster Tester 4 and Premier Tester 7000 are shown in Figure 5.42, 5.43 and 5.44 respectively.

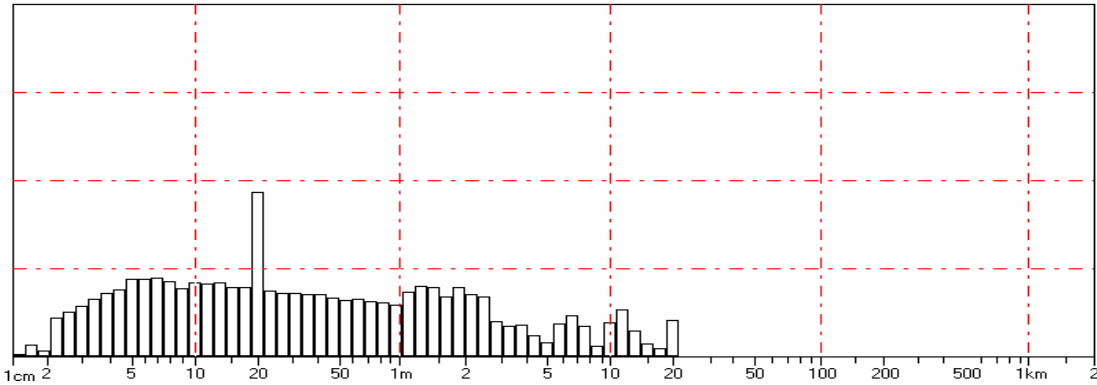


Figure 5.42. Experimentally determined diameter spectrogram of Ne 30-yarn

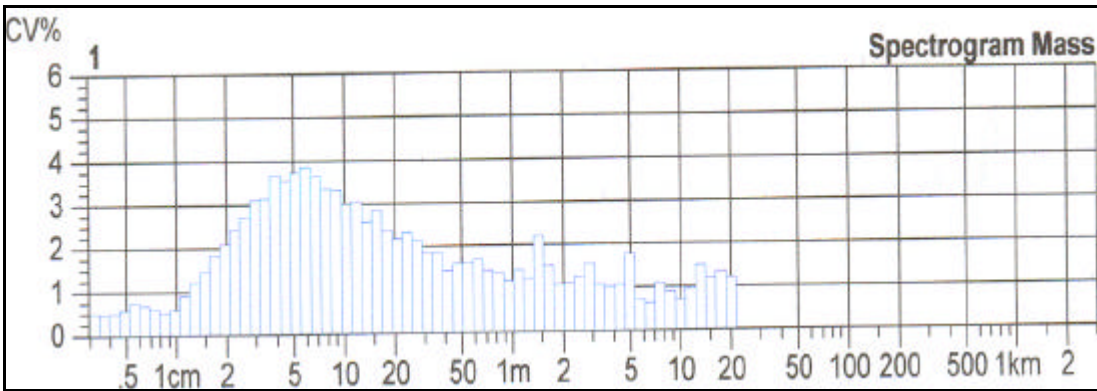


Figure 5.43. Mass spectrogram taken from Uster Tester 4 of Ne 30-yarn

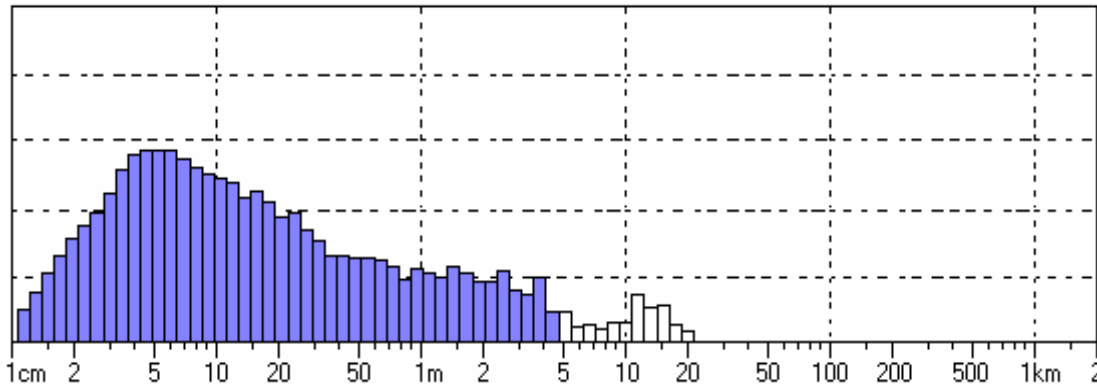


Figure 5.44. Mass spectrogram taken from Premier Tester 7000 of Ne 30-yarn

The histograms of Ne 30 yarn drawn by experimental set-up and Premier Tester 7000 are shown in Figure 5.45 and 5.46 respectively. There was not histogram option in Uster Tester 4.

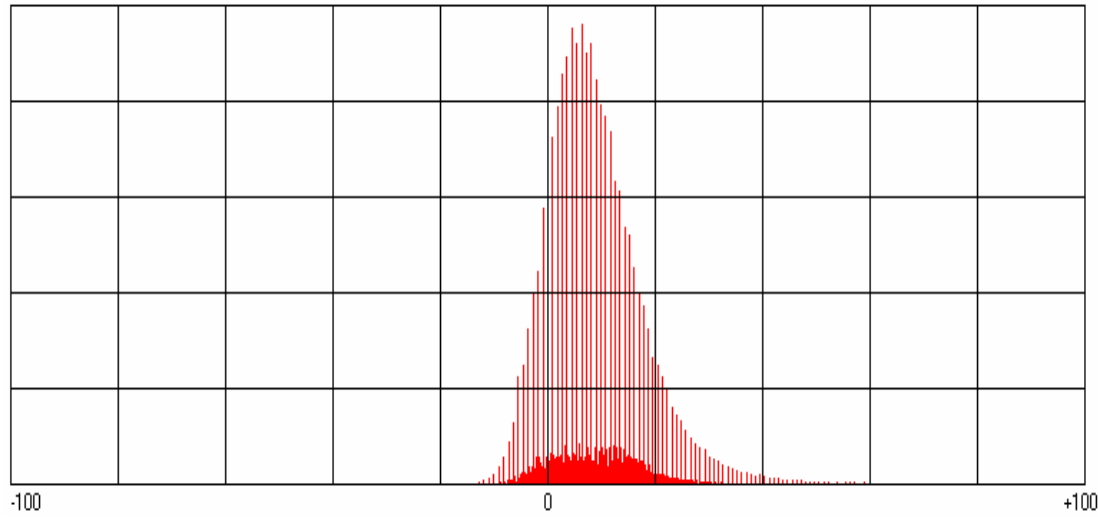


Figure 5.45. Experimentally determined diameter histogram of Ne 30-yarn

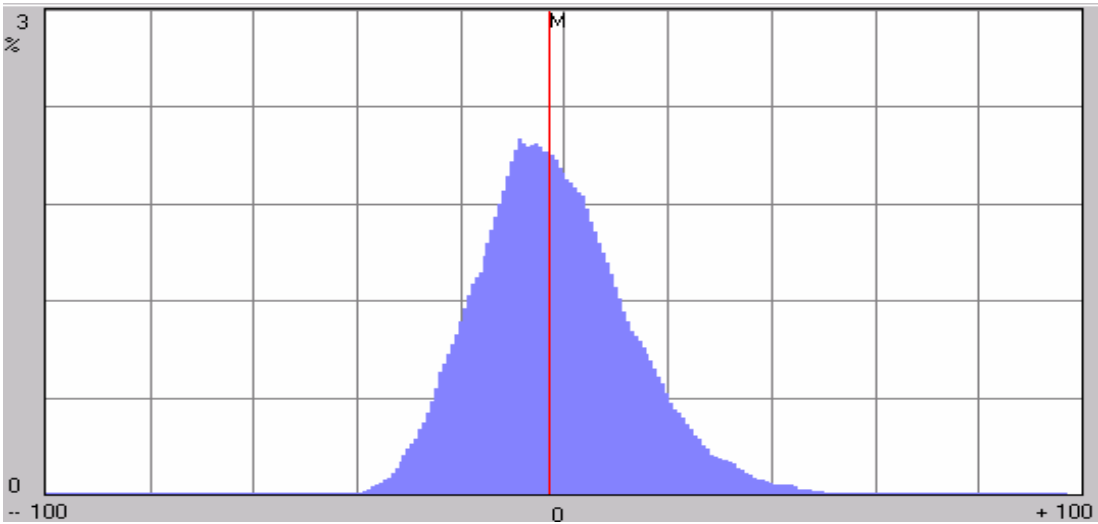


Figure 5.46. Mass histogram taken from Premier Tester 7000 of Ne 30-yarn

CHAPTER 6

CONCLUSION

Yarn evenness copes with yarn fineness variation, measured as variation in mass per unit length along the yarn. Such variations are unavoidable, because they stem from the fundamental structure of textile fibers and from their arrangement. An absolutely regular yarn needs all fiber physical characteristic to be uniformly distributed over the whole yarn. However, this is canceled out by insufficient homogeneities in fiber material and by mechanical constraints in yarn formation, giving limit to achievable yarn evenness.

Consequences of yarn irregularity widespread through all areas of production and uses of textiles, from spinning, weaving and knitting, where yarns tend to break since stresses are applied in these processes, till finishing and dyeing of fabrics, where the construction geometry causes periodic faults in the yarn assembly to locate in patterns very clearly apparent to the eye. Since it is still not possible to produce a yarn without faults, textile industry is searching for sophisticated yarn monitoring systems, able to work during yarn production processes.

Over the years, on-line monitoring systems have mostly concentrated toward obtaining a higher production through reduction of unnecessary frame stoppages and end breakages. Off-line quality control in the laboratory, even with the latest electronic equipment, suffers from certain basic disadvantages such as taking enough samples to adequately represent the population. Delay factor is the most important problem, because a large amount of faulty material can be manufactured before fault detection with a high production capacity of machine. Damage to samples during transportation to the laboratory can also result in inaccuracy of the results. Needing of experienced people to analyze the results is also another disadvantage in off-line control.

These disadvantages can be avoided only with the help of on-line quality monitoring system. On-line evenness monitoring of card and draw frame machines are available in textile industry. The number of end breaks at a ring spinning machine is a measure

of yarn quality. However, on-line evenness monitoring of ring spun yarn hasn't been developed yet. This study, therefore, aims to contribute to on-line quality control of ring spun yarns. For this purpose, the software was designed to analyze mass variations of ring spun yarns.

In this study numerical calculations of quality parameters of yarns such as: unevenness (U_m %), coefficient of variation (CV_m %) and imperfections were calculated by using the designed software. At the same time graphical representation of these parameters such as diagram, spectrogram and histogram were drawn by the designed software.

An experimental setup was prepared to obtain data, which represents the unevenness of yarn. An optic sensor was placed on yarn feed system of Premier Tester 7000 device. The sensor stand manufactured in the workshop of the Mechanical Engineering Department. The study required electrical engineering knowledge for data acquisition and textile engineering knowledge. The results were presented in Chapter 5.

There are parallelisms between numeric values obtained by the designed software available evenness testers such as Premier Tester 7000 and Uster Tester 4. In addition, these parallelisms are valid for diagram and histogram. However, there are differences between spectrograms, because spectrogram requires more sensitive sensors and exact measurement.

Discussion:

One of the most important aspects of the study is the type of the sensors and their properties. Available yarn evenness measurement systems use capacitive or optic sensors. Capacitive sensors are very sensitive to humidity changes in the air, but optic sensors have no this drawback. It may not be suitable to use capacitive sensors in on-line evenness measurement on ring spinning machine, because, it is difficult to keep constant the humidity in vast spinning room. Optic sensors are more suitable than capacitive sensors in on-line yarn evenness measurement because of that reason.

Another important property of sensors is the measuring field length. The measuring field length of capacitive sensors is 8 millimeter, whereas optic sensors have 1 millimeter or lower measuring field length. The lower measuring field length value

enables to measure the yarn variations in lower lengths. From this aspect, optic sensors are superior to capacitive sensors.

Another important property of sensors is the response time. The sensors used in this study have two response time options such as 1 millisecond and 10 milliseconds. The sensors must have adjustable more response time options to measure the yarn evenness at various feed speed of yarn.

The sensors used in this study have one-dimensional measuring principle. One dimensional measuring principle in optic sensors is subject to disturbing influences due to shape effects. This approach is only correct with yarns of approximately round cross-section. Any deviation from the ideal, circular cross-section result in incorrect measurement values, because the non-circular shape is responsible for a large part of the signal which has been interpreted as a diameter variation and therefore result in incorrect data in the thick and thin place number. Because of these reasons, two-dimensional measuring principle is more suitable than one-dimensional measuring principle in optic sensors. With two-dimensional measuring principle, the diameter is measured from two sides, by means of a cross-wise placement of optical transmitters, mirrors and receivers on each side as described in Chapter 5.

Consequently, the sensors used in this study are not sufficient for exact measurement of yarn evenness. Sensors that are more sophisticated are more suitable for this study.

Recommendations :

The further study on this subject may be ordered as follows;

- a) This study may be further developed to on-line calculate evenness, imperfections, neps, long thin places, long thick places and the graphical results by means of the designed software.
- b) A more sensitive sensor may be bought for more exact measurement of yarn evenness.
- c) The yarn fineness measuring system can be improved to measure the hairiness of yarns by adding a suitable sensor to the setup.
- d) This system may be applied to real machines in a factory and the data of all machines can be transferred to a central computer for monitoring of all parameters.

LIST OF REFERENCES

- [1] Corbman, B.P. (1983). *Textiles: fiber to fabric*. (6th ed.). Singapore, McGraw-Hill Book Co.
- [2] Taylor, M.A. (1999). *Technology of textile properties*. (3th ed.). London, Forbes Publication.
- [3] Bilecen, S. (2004). *A study to determine the relationship between yarn quality and spindle speed*. The University Of Gaziantep, Textile Engineering Department.
- [4] Saville, B.P. (2000). *Physical testing of textiles*. Cambridge, Woodhead Publishing Ltd.
- [5] Booth, J.E. (1968). *Principles of textile testing*. Bolton Institute of Technology, J. W. Arrowsmith Ltd.
- [6] www.testrite.co.uk/taper.html
- [7] B.S. Handbook (1963). *Methods of test for textiles*, British Standards Institution No. 11
- [8] [oddservices.co.uk/ lcd/atwork4d.html](http://oddservices.co.uk/lcd/atwork4d.html)
- [9] Chatterjee S.M., Bhattacharyya S., Majumder A. and Mondal A. (2003). Measurement of Mass Variation of Yarn through Interfacing with Computer. *IE (I) Journal-TX*, **vol 84**, pp. 14-20
- [10] Chatterjee S.M., Bhattacharyya S., Majumder A. and Mondal A. (2004, February). On-line Measurement of Yarn Faults through Interfacing with Computer. *IE (I) Journal-TX*, **vol 84**, pp. 21-31.
- [11] Pinto J.G., Monterio J., Vasconcelos R.M., Soares F. (2002). A New System for Direct Measurement of Yarn Mass with 1 mm Accuracy, *IEEE ICIT'02*, Bangkok, Thailand.
- [12] Carvalho V., Pinto J.G., Monteiro J., Vasconcelos R.M., and Soares F. (2003). On-line Measurement of Yarn Evenness, *IEE ICIT'03*, Bangkok, Thailand.
- [13] Jeong S.H. and Suh M.W. (2002). Sequential Channelling of Mass Variations in Spun Yarn Manufacturing Processes, *Textile Research Journal*, **72(8)**, pp. 721-726
- [14] Jasper W., Suh M.W., Kim J. and Lee S (2002). Real Time Yarn Characterization and Data Compression Using Wavelets, North Caroline State University
- [15] Huh You, Suh M.W. (2003). Measuring Thickness Variations in Fiber Bundles with a Flying Laser Spot Scanning Method, *Textile Research Journal*, **73(9)**, pp 767-773
- [16] Wyne, Andrea. (1997). *Textiles the motivate series*, Hong Kong, Macmillan Publishing Company.
- [17] Denton M.J., Daniels P.N. (2002), *Textile terms and definition*. Manchester, The Textile Institue.
- [18] Klein, W. (1993). *The technology of short staple spinning*. Volume 1(2nd ed.). Manchester, The Textile Institue.

- [19] Kadolph S.J., Langford, A.N., Hollen, N And Saddler, J. (1993). *Textiles* (7th ed.). New York, Macmillan Publishing Company.
- [20] Saville, B.P. (2002). *Physical testing of textiles*. Atlanta, West Point-Pepperell Inc.
- [21] Collier, B.J., Epps, H.H. (1999). *Textile testing and analysis*. New Jersey, Prentice Hall.
- [22] Booth, J.E., (1975). *Textile mathematics*. Volume 2. Manchester, The textile Institue.
- [23] Vuru^okan, D. (2003), *On-line quality control of spun yarns*.The University Of Gaziantep, Textile Engineering Department.
- [24] Cook G.J. (1993). Handbook of textile fibers (5th ed.). Merrow Publishing Co.Ltd.
- [25] Barella A. (1997). *Yarn hairiness update*,Textile Progress. Volume 26. Number 4, Manchester, The Textile Institue.
- [26] McAngus, E.H. and Adams, W.W. (1969). *Physical textile testing*. Atlanta, Weast Point-Pepperell Inc.
- [27] Humpries, M. (2000). *Fabric references*. (2nd ed). New Jersey, Prentice Hall.
- [28] <http://www.geocities.com/vijayakumar777/yarnclearing.html>
- [29] Bona, Mario. (1994). *Textile quality; physical methods of product and process control*. Italy, Texilia.
- [30] Skeikh H.R., (2000). *Producing yarn of required quality at competitive prices – I*. Textile Institute of Pakistan.
- [31] Card DK903 Machine Catalogue, Trützschler
- [32] Draw Frame HSR 1000 Machine Catalogue, Trützschler
- [33] Barella A. (1988). *On-line quality control in spinning and weaving*, Textile Progress. Volume 17. Number 1, Manchester, The Textile Institute
- [34] http://www.textilearticle.com/port_links/spinning.htm
- [35] http://unix.barco.com/vision/sensors_&_systems/products/optispin
- [36] Application handbook(2002), *Premier evenness testing*, A Premier Publication.
- [37] Jackson Mike (et al.) (1995). A vision based yarn scanning system. *Mechatronics*, **Vol. 5**, No: 2/3, pp 133-146.
- [38] Application handbook (2002), *Uster evenness testing*, Zellweger Uster.
- [39] <http://www.arl.org/scomm/subversive/glossary.html>
- [40] Karagülle, Ý., Pala, Z. (2003). *Delphi 7*. Türkmen Kitabevi..