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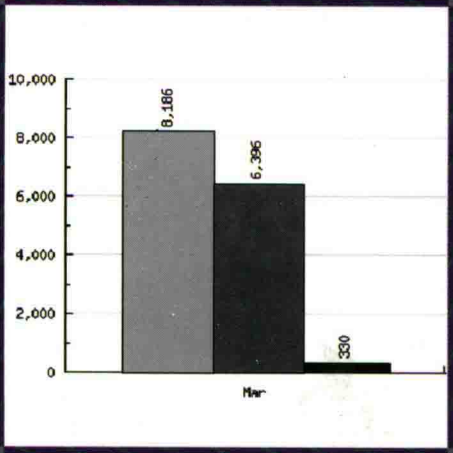

Statistics for textile and apparel management

J. Hayavadana

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Foreword

The role played by statistical techniques in any production system can never be underestimated.

As a matter of fact, in textile production both online and offline quality control techniques are used, and it is needless to say that the apparel industry will be very much benefited by the capability studies, which are purely based on statistical concepts.

Statistical evaluation of the process carried out help us in evaluating the process and eventually increasing the efficiency of the process by alteration of the conditions.

Keeping in view the need for a comprehensive approach to infuse zeal to learn, this book is written in a lucid manner by Prof. J. Hayavadana, Head Textile Technology, University College of Technology (Autonomous), Osmania University, Hyderabad.

The book essentially caters to the need of the students at all levels of textile education. Concepts have been derived from the basics. One specialty of the book is that the topics have been dealt with examples at appropriate stages, and concepts have been demonstrated with worked out examples.

It is imperative that the understanding of any subject is essentially dependent on the person studying but access to study material should be simple on explanation and act as a guide to full of information. The book incorporates both these requirements.

The book is divided in to 11 chapters and in each chapter examples from spinning, weaving and apparel production are covered.

I am sure that this book would be a source of knowledge, and my overall evaluation of the book is positive. I assure that students, staff and technologists working in the industry would find this book very useful.

Dr. P. S. Sampath Kumaran
Retd. Deputy Director
Indian Institute of Chemical Technology
Hyderabad

Preface

I am pleased to release my first book titled "Statistics for Textiles and Apparel Management" to my textile fraternity. Indeed it is a common experience of a student to feel shortage of textile books as compared to other fields and it is a fact also. Statistics is such an important subject without which the business world would have perished. Any product development or production without quality control is like a lifeless object. Textile production is not an exception and any research concludes its results using statistical techniques.

It was my long cherished dream to write a book on statistical methods for textile production and it took nearly 6 years to finalise the topics and book.

The book primarily caters the need to learn basics of statistics in textile production. The book is organized in 11 chapters with examples at each point of discussion. I hope that book will leave up to the expectations of textile world. Any help in the form of suggestions or guidelines, etc., in improving the quality of the book is highly appreciable and will be suitably acknowledged.

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Introduction to statistics in textiles

1.1 Introduction

Statistics is not a new discipline but as old as human society itself. It is not exaggerative if mentioned that no part of technology or social sciences, life sciences, sports or medical sciences, etc., is completed if statistical methods are not used in understanding various concepts. Statistics has been in use since the existence of life on earth. In olden days statistics was regarded as the "Science of Statecraft", but today it is defined as a tool for scientific management, where the decisions are based on the use of statistical tools irrespective of the type of the business activity practiced. Any research study is incomplete if statistics is not applied. 'Statistics' in its connotation is a system of methods or techniques employed for making decisions in the case of uncertainty. Statistics is used for the collection, analysis and interpretation of data in order to provide a basis for making correct decisions. Statistics can be used either in numerical data from or as statistical methods. Statistical methods include all those devices that are used in collection and simplification of large numerical data in such a way that the data is analyzed and understood without difficulty. In short, statistics finds use wherever a mass of quantitative data needs simplification and analysis for meaningful interpretation. Experimental methods are differentiated from statistical methods as the former include the study of various parameters at selected levels. For example, effect of drafting systems with ranges of draft, drafting elements, drafting roller pressures, etc., on yarn quality. But statistical methods are applied to study the effect of the parameters on yarn quality in understanding their significant effect.

The very word 'Statistics' is said to have been derived from Latin word 'Status' or the Italian word 'Statista' or the German word 'Startistik' or the French word 'Statistique' means a political state. In olden days the scope of statistics was limited to only collection of social data which may be governmental or economical for many years. The word 'Statistics' was associated mainly with the analysis of facts and figures to the economic, demographic and political situations prevailing in a country.

Statistics is defined as follows:

It is the aggregate of facts affected to a marked extent by multiplicity of causes numerically expressed, enumerated or estimated according to the reasonable standards of accuracy, collected in a systematic manner for a pre-determined purpose and placed in relation to each other.

Boddington defines statistics as the science of "estimates and probabilities".

Lovitt defines statistics as "the science that deals with the collection, classification and tabulation of numerical facts as the basis for explanation, description and comparison of phenomena".

Statistics is used in the form of statistical methods, applied statistics, descriptive applied statistics and scientific applied statistics. The word "statistics" means numerical statement of data collected from various sources; use of scientific methods to analyze the collected data for quick, accurate and easy interpretation; a measure to evaluate the data collected.

The above facts can be very well understood if examples from textile/apparel field are considered:

1. The production of a synthetic fibre (staple fibre) or filament (partially oriented yarn) or twisted yarn or finished fabric from a firm (here statistics is referred for analyzing the data collected).
2. Consider two yarns are produced from the same mixing but spun on the same or different frames. The objective is to find whether the two yarns produced on the same frame are differing or the frames are differing. This can be very well understood by analyzing the data and using a suitable statistical tool like significance testing (here statistics is used to represent the statistical methods).
3. Consider analysis of plain fabric samples with observations of threads per cm, crimps (warp × weft) and count (warp × weft) to assess the nature of clothes as warp faced, light weight, medium weight or heavy weight, close set, open set, etc. (here statistics is used to analyze the set of observations).

The word "statistics" is used as plural and singular. In its plural form it refers to the numerical data collected in a systematic manner with some definite objective. In singular form, it means the science of statistics or the subject itself including the methods, principles with collection, analysis and interpretation of numerical data under consideration. Statistics is defined in many ways. One of the simple ways is to define statistics as a "science of collecting, presenting, analyzing and interpretation of numerical data under consideration". A number of definitions are made available in the statistics books and the reader is instructed to refer in case of need. However, in modern days, statistics is viewed not only as mere devise for collecting the numerical data but also as means of developing techniques

for their analysis and interpretation and thus drawing interferences on scientific basis. To understand this one can consider production of several types of garments produced by typical apparel units to select the best group of readymade garments using multivariate analysis technique with or without the help of SPSS.

1.2 Salient features of statistics

Statistics is a multifacinated subject applicable to all types of production/ testing/manufacturing processes.

1. The data collected can be expressed as primary or secondary data.
2. In the research data, the present shift can be calculated helping in understanding the effect of change made in the substrate (e.g., the changes in bending – length/drape). Crease recovery angle from control to finished/changed state can be understood by computing percent shift. Positive or negative value of shift is interpreted according to the property under consideration).
3. The data helps in understanding about the population.
4. In textile production, statistics forms the basis for process settings and process control.
5. Statistics is the aggregate of facts.
6. Statistical data is expressed numerically and thus has a potential for further editing, retrieving or processing.

1.3 Functions of statistics

1. The techniques of statistics examine the relationship between the variables (e.g., relation between thickness and air permeability; rigidity and drape; load and elongation; threads/inch and cover factor, etc.).
2. The method of statistics aims in simplifying the complex data (for e.g., consider the selection of polyester dress materials of two groups, low and high twisted, and these samples be heat set at various temperatures in stenter in tant and black form. Subsequently scored or weight reduced with a number of parameters like material to liquor ratio, caustic%, etc, leading to a great or larger sample size. Let these fabrics be tested for 16 mechanical properties of KES-F and FAST. It is necessary for an experimenter to select best fabric in terms of THV or TAV. The statistical data is analyzed systematically for results).
3. Statistics aims at comparison of two different processes (for e.g., comparing the efficiency and properties of conventional and enzyme-scoured fabrics).

4. It presents the experimental data in a simple form.
5. It helps in decision-making process as the techniques are used in forecasting and planning.
6. Statistics also help in designing, framing policies for different types of management in government or business organizations.
7. Variability in any process can very well be analyzed or studied by using statistical tools.

1.4 Applications of statistical tools in various processing stages of textile production

1.4.1 Fibre production

Measures of central tendency like process average gives an idea about average staple length of fibre produced in a continuous or batch wise process. Coefficient of variation (CV) of the process signifies about the process control. On the other hand, analysis of time series is helpful in estimating the future production based on the past records.

Measures of dispersion such as standard deviation and CV are useful in comparing the performance of two or more fibre-producing units or processes. Significance tests can also be applied to investigate whether significant difference exists between the batches for means or standard deviations. Analysis of variance can be applied for studying the effect of parameters of fibre production and methods of polymer dissolving.

1.4.2 Textile testing of fibres, yarns and fabrics

Results analysis in textile testing without the applications of statistical tools will be meaningless. In other words every experiment in textile testing include the use of statistical tools like average calculation, computation of SD, CV and application of tests of significance (t-test, z-test and f-test) or analysis of variance (one way, two way or design of experiments). Populations can be very well studied by normal or binomial or Poisson's distributions. Random sampling errors are used in studying about the population mean and SD at 95% and 99% level of confidence. Application geometric mean for finding out the overall flexural rigidity or G_o has an important role in fabric selection for garment manufacture.

A special mention is made in determination of fibre length by bear sorter where all the measures of central tendency and dispersion (mean length, modal length quartile deviation, etc., in the form of frequency distribution) are computed to understand about the cotton sample under consideration for testing its potential in yarn manufacture. On the other hand ball sledge sorter uses weight distribution from which mean and

SD are computed. In the case of cotton fibres, the development of cell wall thickening commonly referred as "Maturity" concept can be very well determined using normal distribution and confidence intervals. Several properties are tested for different packages produced from the same material or from the same frame by applying significance tests. Effect of instruments and variables for different types of samples can be very well studied by using ANOVA. All the fabric properties tested on a single instrument or different instrument can be understood by using design of experiments. In one of the research applications, which include the testing of low stress mechanical properties for nearly 1000 fabrics are studied by 'Principle Bi component analysis or Bi plot'. Measures of dispersion like coefficient of variation and percentage mean deviation are very much used in evenness measurement.

1.4.3 Yarn production

There are several stages involved in the cotton yarn production. When fibres are mixed and processed through blow room, within and between lap variations are studied by computing mean, SD and CV lap rejection, and production control are studied by $\overline{p}$ and $\overline{x}$ charts. Average measure is used to find the hank of silver in carding, draw frame, combing and average hank of roving in roving frame and average count at ring frame. Generally the spinning mill use 'average count' as the count specification if it is producing 4–5 counts. On the other hand the weaving section uses 'resultant count' which is nothing but the harmonic mean of the counts produced. Control charts are extensively used in each and every process of yarn production (for example, the process control with respect to thin places, neps, etc.). Application of probability distributions like Poisson, Weibull and binomial for various problems in spinning is found very much advantageous to understand the end breakage concept. In ring spinning section several ring bobbins are collected and tested for CSP and difference between the bobbins and within the bobbins is studied using 'range' method. In cone winding section the process control can be checked either by using control chart for averages or chart for number defectives.

1.4.4 Fabric production

Design of experiments such as latin square design or randomized block design can be used to identify the effect of different size ingredients on wrap breakages on different looms in fabric formation. Most of the suiting fabric constructions involve the use of double yarn which is nothing but the harmonic mean of different counts. Poisson's and normal distribution

can be applied for loom shed for warp breakages. Using statistical techniques the interference loss can also be studied in loom shed. Various weaving parameters such as loom speed, reed and pick can be correlated with corresponding fabric properties and are interpreted in terms of loom parameters. Control charts are used to study the control of process/product quality in fabric production also. For example, selection of defective cones in a pirn winding from a lot (fixed population) or in a production shift n $\bar{p}$ and $\bar{p}$ charts are used. The width of the cloth and its control can be understood by $\bar{x}$ and defectives per unit length and their control is understood by $\bar{c}$ charts. The testing process includes determination of average tensile strength (and single thread strength also) and the corresponding CV%.

1.4.5 Chemical processing and garment production

The scope of statistics is unlimited. For example the effect of n number washes (identical conditions) on m fabrics on a particular fabric property can be easily found by either tests of significance or analysis of variance. Similarly the effect of different detergents on fabric types can be investigated by two-way analysis of variance. Similarly different types of fabrics and the effect of sewing conditions can be studied by ANOVA.

In garment production the control of measurements and its distribution can be well understood by control and polar charts.

1.5 Scope of statistical techniques in textile production

The scope of statistics in analyzing the performance of machines or equipments is mentioned below.

1.5.1 Measures of central tendency and frequency distribution

Study of average pick spacing, average count in two or more spinning mills, average weft insertion rate in shuttles looms, less than or more than ogives for computing the number of end breaks in weaving and ring spinning, cumulative frequency of fibre length and fabric GSM, fineness by torsion balance measurement, number of defective rolls of fabric, bivariate frequency distribution of single thread strength or tensile strength and elongation plotting of idle time and down time of spindles in ring frame, yarn clearing and tensioning in cone winding, frequency distribution of linear density of yarns, end breaks in winding, warping, etc.

Use of mean in wettability of fabrics, felting of wool test, fibre length distribution in different bales, permanganate values (in ppm) of a dye effluent factory, distribution showing time taken for doffing and donning in ring frame, and winding, warping and sizing processes; calculation of mean length of garments in garment unit. Geometric mean is used in one of the incentive wage payment system, and weighted mean is used in fibre length distribution. Mean is also used to know the mean yarn tpi in a mill producing wide range of twisted yarns.

1.5.2 Use of standard error, confidence intervals

Standard error is used for sample mean and population and hence the limits are known.

Standard error and CV also give an idea about the number of tests to be carried out to keep the error at a known level.

The concept is also useful to known the limits of moisture content of yarn sample. The same explanation also holds good in case of linear density, extension at break, etc.

1.5.3 Statistical distributions

Normal, Poisson's and binomial distributions are applied in most of the testing cases like water proof or rain coat, to find the average number of coats that are expected to be water proof or probability of coats failing in the test or machine break downs, end breaks in weaving, end breaks in ring spinning, etc. When a roll of fabrics is checked for defects, by using these probability distributions, it is possible to know whether the price will contain more than one defect or no defects.

1.5.4 Correlation and regression

Correlation between fibre maturity and micronaire values can be found by Karl Pearson's co-efficient. Correlation is applied for determining the correlation between:

(i) Dye up take and fibre structure.
(ii) Drafting roller pressure and imperfections.
(iii) Bleaching (whiteness index) and dye up take.

Regression analysis is applied in different situations. Some of the examples are the following:

(i) Relation between processing tension and modules of tire cord yarns.
(ii) Shrink-resist finish and percent area shrinkage.