APPLICATION OF MATHEMATICAL STATISTICS IN THE TEXTILE INDUSTRY

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Annotation: This article explores the application of mathematical statistics methods in the textile industry across all stages of the production cycle—from raw material analysis to quality control of finished products. It shows how statistical approaches contribute to the optimization of technological processes, failure prediction, and reduction of defects. Special attention is given to the integration of statistical methods into the digital environment, including data collection systems, machine learning, digital twins, and BI tools. Practical tasks and solutions are provided to illustrate the real use of statistics in manufacturing. The contribution of leading scientists to the development of statistics as an applied science is also highlighted. The work emphasizes the key role of mathematical statistics in increasing the efficiency, sustainability, and intelligence of modern textile enterprises.

1. Introduction

Mathematical statistics is a vital tool amid the rapid development of industry and the need to make precise decisions based on the analysis of large volumes of data. This is particularly relevant in the textile sector, where processes are influenced by numerous variables: raw material quality, technological conditions, equipment settings, and the human factor. Data analysis using statistical methods not only supports consistent product quality but also enables system behavior prediction, production flow optimization, and defect and loss prevention. Integrating mathematical statistics into textile manufacturing is a crucial step toward creating an intelligent and adaptive production cycle.

2. Scientific Definition of the Topic

Mathematical statistics is a branch of applied mathematics that studies the methods of collecting, processing, analyzing, and interpreting numerical data to obtain objective conclusions about the parameters and structure of random phenomena. It is based on probability theory and is aimed at making decisions under conditions of uncertainty.

The main tasks of mathematical statistics include: data description, generalization and interpretation, identification of patterns and systematic deviations, and building predictive models. In the textile industry, statistics are used at the stage of input raw material analysis, during quality control, in optimizing logistics and production chains, and in implementing data-driven management systems.

3. Application of Mathematical Statistics in the Textile Industry

Mathematical statistics is used throughout the entire production cycle in the textile industry — from raw material input analysis to final product quality assessment. Key application areas are discussed below:

Quality Control of Products

Statistical methods help detect defects, determine average values of fabric and fiber density, thickness, strength, and evaluate their deviations.

The use of Shewhart control charts, variance analysis, and tolerance studies is standard practice in factories producing yarn, fabrics, and finished goods.

Optimization of Production Processes

Collecting statistical data on machine operating time, wear of parts, speed, and deviations allows to:

- Optimize technological parameters
- Reduce downtime
- Improve shift efficiency and production coefficients

Raw Material Property Research

Before launching a new type of fiber, samples are analyzed for strength, length, and uniformity. Sampling estimates and variance analysis are used.

Predictive Analytics

Based on historical data, it is possible to predict the probability of defects, supply disruptions, or equipment failures. Regression analysis, machine learning, and time series methods are applied.

Logistics and Inventory Management

Mathematical statistics methods are used to calculate optimal order volumes, average material consumption, and seasonal fluctuations.

Impact on Managerial Decision-Making

Textile company management uses statistics for:

- Employee KPI calculation
- Production planning
- Evaluation of marketing strategy effectiveness

4. Practical Tasks for Application in the Textile Industry

Task 1: Fabric Density Control

Condition: A textile factory measured the fabric density (in g/m^2) for 20 samples from a single batch. It is necessary to determine the average density, variance, and the 95% confidence interval.

Density values table:

Solution:

Mean value:

$\bar{X}$ = (sum of all values) / 20 = 3055 / 20 = 152.75 g/m²

Sample variance:

$S^2 \approx 4.28$

Standard deviation:

$S = \sqrt{4.28} \approx 2.07$

Confidence interval (confidence level 95%, t for n=20):

T = 2.093

Margin of error = $t \times (S / \sqrt{n}) = 2.093 \times (2.07 / \sqrt{20}) \approx 0.97$

Interval: 152.75 ± 0.97 → [151.78; 153.72]

Answer:

Average density: 152.75 g/m²

95% confidence interval: [151.78; 153.72] g/m²

Task 2: Hypothesis Testing on Defects

Condition: In a 200-meter fabric sample, 14 meters had defects. Check whether the defect rate exceeds the acceptable norm (5%) at a significance level of 0.05.

Hypotheses:

H_0: p = 0.05

H_1: p > 0.05

Solution:

Proportion estimate:

$\hat{P}$ = 14 / 200 = 0.07

Z-score:

$Z = (\hat{P} – P_0) / \sqrt{(P_0(1 – P_0) / n)}$

$Z = (0.07 – 0.05) / \sqrt{(0.05 \times 0.95 / 200)}$

$Z \approx 0.02 / 0.0154 \approx 1.30$

Critical Z-value (significance level 0.05, one-sided): 1.645

Conclusion:

Since $Z < 1.645$, the null hypothesis H_0 is not rejected. The batch meets the standard.

Correlation and regression

Assess relationships between variables. For example, used to study the connection between fabric density and weaving speed.

Analysis of variance (ANOVA)

Method for comparing several groups by their means. In textiles, used to analyze the influence of different factors on material properties.

Quality control methods

Shewhart charts, control charts

Used to monitor process stability

Integration of Mathematical Statistics into the Digital Environment and Automation

Modern textile manufacturing is actively transitioning to digital technologies. The use of mathematical statistics in combination with information systems is transforming approaches to management, quality control, and forecasting. Key integration areas include:

- Data Collection and Analysis Systems (SCADA, MES)
- Sensors and detectors installed in textile workshops transmit data on temperature, humidity, equipment speed, etc.
- Statistical analysis systems process this data in real time, identifying anomalies and trends

Tools used: control charts, KPI analytics, regression models

Predictive Analytics and Machine Learning

Historical production data, defect records, maintenance logs, and delays are used to build predictive models

Machine learning (ML) and time series analysis help:

Predict machine breakdowns

Identify defect risks under certain conditions

Optimize production schedules and shift loads

AI-Based Quality Control Systems

Visual inspection systems (e.g., computer vision) combined with statistical methods allow automation of:

- Fabric defect detection
- Sample-to-standard comparisons
- Defect classification

Integration with ERP and BI Systems

Business Intelligence (BI) tools create dashboards for visualizing statistical metrics

ERP systems gather statistics on supplies, costs, and inventory

Techniques: cluster analysis, ABC/XYZ analysis, statistical cost modeling

Digital Twins of Production

Virtual copies of processes are created using statistical models to:

- Test new conditions
- Analyze change impacts without risk
- Run optimization simulations

Use of Cloud Platforms and Big Data

Large volumes of statistical data are stored and processed in cloud systems

Technologies: Spark, Hadoop, analytical SQL queries, Python (NumPy/Pandas)

Benefits:

Integration of statistics into digital infrastructure makes textile production:

- Flexible, responding to changes
- Transparent, with parameters tracked and predicted

- Efficient, with optimized costs and stable quality

Conclusion

Mathematical statistics is an essential part of modern scientific and applied tools in the textile industry. Its application spans all production stages: from raw material analysis to finished product quality control, logistics management, and evaluation of technological effectiveness.

Thanks to statistical methods, enterprises can:

- Objectively assess product quality
- Identify and eliminate defect causes in time
- Optimize resources and production schedules
- Build reliable forecasts and scenarios
- Improve efficiency and process sustainability

The integration of statistical approaches into digital infrastructures (ERP, BI, machine learning, sensor networks) has enabled a leap from traditional to smart factories—intelligent systems managed through data.

Thus, mathematical statistics not only strengthens the scientific foundation of textile production but also becomes a driver of its technological and digital development. Its role will continue to grow alongside increasing automation and the demand for precise, data-based decisions.

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