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.

Аннотация:В статье рассматривается применение методов математической статистики в текстильной промышленности на всех этапах производственного цикла — от анализа сырья до контроля качества готовой продукции. Показано, как статистические подходы способствуют оптимизации технологических процессов, прогнозированию отказов и сокращению дефектов. Особое внимание уделено интеграции статистических методов в цифровую среду, включая системы сбора данных, машинное обучение, цифровых двойников и инструменты BI. Приведены практические задания и решения, иллюстрирующие реальное использование статистики в производстве. Также отмечен вклад ведущих ученых в развитие статистики как прикладной науки. В работе подчеркивается ключевая роль математической статистики в повышении эффективности, устойчивости и интеллектуальности современных текстильных предприятий.

1. Introduction

Mathematical statistics is a vital tool in the context of rapid industrial development and the need to make accurate decisions based on the analysis of large amounts of data. This is especially true in the textile industry, where processes are affected by numerous variables: raw material quality, process conditions, equipment settings, and the human factor.

Data analysis using statistical methods not only maintains constant product quality, but also allows predicting system behavior, optimizing production flow, and preventing defects and losses. The integration of mathematical statistics into textile production is an important step towards creating an intelligent and adaptive production cycle.

1. Scientific definition of the topic

Mathematical statistics is a section 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 uncertainty.

The main tasks of mathematical statistics include: description, generalization and interpretation of data, identification of patterns and systematic deviations, construction of predictive models. In the textile industry, statistics are used at the stage of analysis of incoming raw materials, in quality control, in optimization of logistics and production chains, in the implementation of data-driven management systems.

1. Application of mathematical statistics in the textile industry

Mathematical statistics are used throughout the production cycle in the textile industry - from the analysis of incoming raw materials to the assessment of the quality of the final product. The main areas of application are discussed below:

Product quality control

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

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

Optimization of production processes

Collection of statistical data on machine operating time, component wear, speed and deviations allows:

• Optimization of process parameters

• Reduction of downtime

• Increased shift efficiency and production rates

Study of raw material properties

Before launching a new type of fiber, samples are analyzed for strength, length and homogeneity. Sample assessments and dispersion 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 used.

Logistics and inventory management

Mathematical statistics methods are used to calculate optimal order volumes, average material consumption and seasonal fluctuations.Impact on management decision-making

The management of a textile company uses statistics to:

• Calculate employee KPIs

• Plan production

• Assess the effectiveness of a marketing strategy

1. Practical tasks for use in the textile industry

Task 1: Fabric density control

A textile factory assessed the fabric density (in g/m²) for 20 samples from one batch. It is necessary to determine the average density, variance, and 95% confidence interval.

Density Value Table:

Solution:

Mean:

$\bar{X}$ = (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 (95% confidence level, t for n=20):

T = 2.093

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

Interval: $152.75 \pm 0.97 \rightarrow [151.78; 153.72]$

Answer:

Average density: 152.75 g/m²

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

Problem 2: Testing the hypothesis about defects

Condition:

In a 200-meter-long fabric sample, 14 meters had defects. Check whether the level of defects exceeds the permissible norm (5%) at a significance level of 0.05.

Hypotheses:

H_0: $p = 0.05$

H_1: $p > 0.05$

Solution:

Proportion Score:

$P' = 14 / 200 = 0.07$

Z-Score:

$Z = (P' - P_0) / \sqrt{(P_0(1 - P_0) / n)}$

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

$Z \approx 0.02 / 0.0154 \approx 1.30$

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.

Problem 3: Comparison of shift productivity

Condition:

Average output of the first shift is 158 m, $\sigma_1 = 5$, $n_1 = 30$

Average output of the second shift is 155 m, $\sigma_2 = 4$, $n_2 = 30$

Determine whether the difference is statistically significant at $\alpha = 0.05$.

Hypotheses:

H_0: $\mu_1 = \mu_2$

H_1: $\mu_1 \neq \mu_2$

Solution:

Difference in means:

158 – 155 = 3

Standard error:

$\sqrt{(\sigma_1^2 / n_1 + \sigma_2^2 / n_2)} = \sqrt{(25 / 30 + 16 / 30)} = \sqrt{1.37} \approx 1.17$

Z-score:

$Z = 3 / 1.17 \approx 2.57$

Critical Z-value (two-tailed test, $\alpha = 0.05$): ±1.96

Conclusion:

Since $Z > 1.96$, the null hypothesis is rejected. The difference between the shifts is statistically significant.

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