

ABSTRACT

of the dissertation by Murzabayeva Gulzhan Koblanbekovna, submitted for the degree of Doctor of Philosophy (PhD) under the educational programme 8D07206 – "Technology and Design of Textile Materials"

Dissertation title: Calculation and optimization of the technological process of carding fibers in a carding machine to improve the quality of the produced yarn.

Aim of the study: To enhance the competitiveness of the manufactured product by investigating the effect of fibre property changes at the technological stages of the spinning process on the properties of the resulting yarn.

To achieve the stated aim, the following objectives were formulated:

- to evaluate the effect of the carding process on the physical and mechanical properties of the resulting yarn and the potential for their improvement;
- to experimentally investigate the effect of flat speed on the carding machine on the properties of the sliver and yarn;
- to experimentally investigate the effect of taker-in speed variation on yarn properties;
- to calculate the overall degree of carding in the "main cylinder – flats" zone;
- to experimentally investigate the effect of carded product delivery speed on the quality indicators of yarn;
- to experimentally determine the optimum speed parameters of the working elements of the carding machine;
- to develop mathematical models that, in the course of a theoretical investigation of the technological parameters of the carding machine, enable the identification of factors affecting changes in the properties of the processed raw material and the quality of the output product.

Research methods.

The research employed methods for assessing the quality of semi-finished products and yarn, mathematical statistics and computational mathematics, computer software, as well as modern measurement techniques and evaluation tools.

Main provisions submitted for defence (proven scientific hypotheses and other conclusions constituting new knowledge):

- analysis of the effect of varying flat movement speed on the quality of sliver and yarn;
- the effect of changes in taker-in speed regimes on yarn unevenness, imperfections, hairiness, and tenacity;
- the effect of carded product delivery speed on the quality indicators of the resulting yarn;
- optimum speed regimes of the principal working elements of the carding machine;

– development of mathematical models enabling the identification of factors affecting the quality of sliver and yarn properties.

Principal results of the research:

Scientific results of practical significance were obtained in the course of the study.

1. A review of scientific sources demonstrated that changes in fibre quality parameters arising from adjustments to technological equipment and variations across processing passages inevitably affect yarn properties; however, the correlation between yarn properties and the conditions of yarn structure formation has not been scientifically substantiated. Furthermore, descriptions of yarn structure have not accounted for its dependence on the technological and kinematic parameters of the carding machine, and no methods for selecting process parameters aimed at improving yarn quality have been developed at manufacturing enterprises.

2. A comparative analysis of the scientific literature identified the central scientific problem, which consists in the need to develop recommendations for controlling yarn characteristics, taking into account fibre changes across processing passages, yarn formation parameters, and yarn properties.

3. It was demonstrated that the carding process exerts a significant influence on the physical and mechanical properties of yarn produced in spinning and on the possibility of their improvement.

4. The effect of flat speed on the carding machine on sliver and yarn properties was investigated experimentally. The study showed that as flat speed increased, short fibre content (SFC) and unevenness (U%) decreased, and that at a flat speed of 320 mm/min the quality of sliver and yarn improved considerably. Based on the findings, a flat speed of 320 mm/min is recommended as the effective operating speed.

5. The effect of taker-in speed on yarn properties was investigated experimentally. It was established that as taker-in speed increased, sliver unevenness at the second drawing passage decreased, and yarn unevenness (U%), imperfections (IPI), and hairiness (H) likewise decreased, whereas yarn tenacity (cN/tex) was reduced.

6. The overall degree of carding in the "main cylinder – flats" zone of the carding machine was calculated. Analysis of data on fibre residence time in the carding zone and the degree of carding demonstrated that increasing the surface speed of the main cylinder leads to a reduction in the mean fibre residence time within the flat clothing for carding machines of the C60 and TS-03 types.

7. The effect of carded product delivery speed on yarn quality indicators was investigated experimentally. As delivery speed increased from 180 min⁻¹ to 210 min⁻¹, yarn unevenness (U%) increased slightly, imperfections rose continuously, tenacity decreased from 16.8 cN/tex to 16.0 cN/tex, hairiness increased moderately from 4.2% to 4.8%, and yarn elongation decreased from 5.42% to 5.25%. Consequently, it was established that increasing the delivery speed of the carded product leads to a deterioration of yarn quality indicators.

8. The optimum speed regimes of the carding machine were determined experimentally. The following optimum speed parameters for the working elements of the carding machine were recommended: taker-in speed — 1260 min^{-1} , main cylinder speed — 520 min^{-1} , and flat speed — 320 mm/min .

9. In the course of a theoretical investigation of the technological parameters of the carding machine, equations were derived on the basis of a mathematical model describing the parameters of card sliver unevenness ($U\%$) and relative yarn tenacity (R_{km}), grounded in the experimental results. The regression mathematical models obtained adequately represented the investigated process with sufficient accuracy.

Justification of the novelty and significance of the results obtained:

- The effect of fibre quality changes associated with equipment settings and passage variations on yarn properties was analysed. As a result, the dependence of the physical and mechanical properties of sliver and yarn on the technological and kinematic parameters of the carding machine in spinning production was established.

- The effect of flat movement speed on the carding machine on sliver and yarn properties was investigated. Based on the findings, a flat speed of 320 mm/min is recommended as the effective operating speed.

- It was established that as taker-in speed increases, sliver unevenness at the second drawing passage decreases, and yarn unevenness ($U\%$), imperfections (IPI), and hairiness (H) likewise decrease, whereas yarn tenacity (cN/tex) is reduced.

- Analysis of data on fibre residence time in the carding zone and the degree of carding revealed that increasing the surface speed of the main cylinder leads to a reduction in the mean fibre residence time within the flat clothing of the carding machine.

- It was established that as the delivery speed of the carding machine increases from 180 min^{-1} to 210 min^{-1} , yarn unevenness ($U\%$) increases, imperfections rise continuously, tenacity decreases from 16.8 cN/tex to 16.0 cN/tex , hairiness increases from 4.2% to 4.8% , and yarn elongation decreases from 5.42% to 5.25% . It was determined that increasing the delivery speed of the carded product leads to a deterioration of yarn quality indicators.

- The optimum speed parameters of the working elements of the carding machine that improve the quality indicators of the resulting sliver and yarn were identified.

- Mathematical models based on multifactorial experimental design were developed for determining card sliver unevenness ($U\%$) and relative yarn tenacity (R_{km}).

- The incorporation of the results and practical recommendations obtained in the course of this research into the production regulations of spinning enterprises will enable a systematic improvement in the physical and mechanical properties of yarn and ensure the competitiveness of the finished product.

Alignment with directions of scientific development or state programmes:

The dissertation was carried out in accordance with the state-funded research plan of the Department of Technology and Design of Textile Materials at M. Auezov South Kazakhstan University under the research topic B-21-09-07 – “Innovative Textiles. Principles of Shape Formation and Decoration.”

The dissertation research corresponds to the priority area of science development in the Republic of Kazakhstan, namely, “Natural resources conservation, including water resources, geology, recycling, new materials and technology, safe products and structures.” The completed dissertation research is aimed at the rational use of natural raw materials in the textile industry and at improving the quality of the resulting textile products.

The doctoral candidate's contribution to the preparation of each publication:

All analytical and experimental work during the course of the doctoral research was carried out by the candidate personally, with the participation of the scientific consultant. A total of nine scientific papers were published on the dissertation topic, including two articles in journals indexed in the Scopus database and two articles in publications included in the list of the Committee for Quality Assurance in the Sphere of Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan, five articles in collections and materials of international scientific and practical conferences. The content of the articles reflects the principal substance of the dissertation.

1. Article "Determination of the Optimum Speed Mode of the Carding Machine" in the *International Review of Mechanical Engineering (I.R.E.M.E.)* — preparation of the literature review, acquisition, processing, and discussion of experimental data.

2. Article "Impact of taker-in speed on the characteristics of ring-spun yarn" in the journal *Industria Textilă* — data collection, data processing, and interpretation of results.

3. Article "The effect of changes in technological regimes of carding on the quality indicators of sliver and yarn" in the scientific journal *Vestnik EKTU* — preparation of the literature review, acquisition of experimental data, and data visualisation.

4. Article "The effect of carding speed on yarn quality indicators" in the scientific journal *Mechanics and Technologies* — data collection, acquisition of experimental data, and data processing.

5. Article "Analysis of the design of modern carding machines" in the proceedings of the XI International Scientific-Practical Conference "Machine Learning Today, Prospects and Threats" (*Eurasian Education, Science and Innovation Journal*) — literature review and compilation of materials.

6. Article "Factors affecting the efficiency of flats on the carding machine" in the proceedings of the International Scientific-Practical Conference "Auezov Readings – 20: The Heritage of Mukhtar Auezov — A National Treasure",

dedicated to the 125th anniversary of M. O. Auezov — literature review, collection and processing of materials.

7. Article "Determination of fibers' non-combed part length held by flats" in the proceedings of the International Scientific-Practical Conference "Industrial Technologies and Engineering – ICITE-2022" — data collection, data acquisition, and processing of results.

8. Article "The influence of increasing the productivity of the carding machine on the quality indicators of the card sliver" in the Scopus-indexed conference proceedings *E3S Web of Conferences 474, 01024 (2024)*, *ICITE 2023* — preparation of the literature review, data acquisition, and visualisation.

9. Article "The influence of the average residence time of the fiber in the set of the main drum and the flats of the carding machine on the carding degree" in the Scopus-indexed conference proceedings *E3S Web of Conferences 474, 01024 (2024)*, *ICITE 2023* — data collection, data processing, and interpretation of results.