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PAPER

TECHNOLOGY FOR MANUFACTURING LIGHTWEIGHT SPINDLES OF COTTON-PICKING MACHINES

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Abstract

Nowadays, a wide variety of cotton harvesting machines are manufactured in different countries to collect the cotton crop. Among them, vertical spindle cotton harvesters occupy a unique position in the development of the cotton industry and harvesting machinery, despite their slightly lower harvesting efficiency compared to some other types. Throughout their evolutionary development, vertical spindle cotton harvesters have undergone numerous structural and technological modifications. However, the main working element—the spindle system—still presents significant challenges. Extensive experimental studies have been conducted by numerous researchers to improve spindle performance. Although several spindle designs have been proposed, none have yet fully resolved all existing issues. One of the most pressing problems is the relatively heavy mass of the spindle, which places excessive mechanical load on the driving mechanisms. As a result, these mechanisms often suffer from reduced operational reliability and tend to fail prematurely, before the end of their intended service life. This article presents a step-by-step analysis of the design and production technology of a lightweight spindle structure developed in accordance with modern engineering requirements. The proposed technological solution aims to enhance the overall efficiency of vertical spindle systems, improve operational performance, and extend the service life of the cotton harvester's core components.

Key words: lightweight design, cylinder sector, radially bent edges.

Introduction

Cotton-picking machines with vertical spindles have seen significant changes over time. Despite advancements, issues related to spindle weight and durability remain unresolved. The excessive mass of the spindle contributes to early failure of the driving mechanism, resulting in higher maintenance costs and decreased machine efficiency. This study focuses on developing a lightweight spindle construction to improve efficiency, durability, and overall performance. The research also includes an in-depth mechanical analysis of different spindle configurations.

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Research Methods and the Received Results

Spindle Evolution and Testing. The spindle diameter has been tested within the range of 18 mm to 36 mm. In mass production, the following spindle types have been utilized: 24 mm (solid metal), 28 mm (shelled), 28–29 mm (screw-type). The drive mechanism employs a planetary gear system with 8–15 spindles acting as satellites. Durability tests were conducted under operational conditions to assess wear resistance and failure rates.

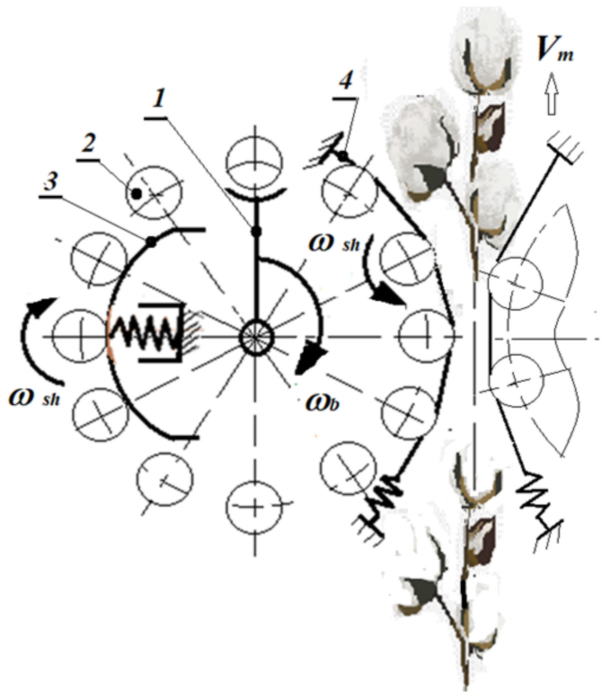

Figure 1. Spindle drive mechanism

ω_b – Angular velocity of the spindle drum (carrier); ω_s – Angular velocity of the spindle (satellite); 1 - Spindle drum (carrier); 2 - Spindles (satellites); 3 - Brake pad providing reverse motion to the spindles (satellites); 4 - Belt providing forward motion to the spindles.

Design of the Lightweight Spindle. The proposed lightweight spindle features a shell structure with radially bent edges, designed to enhance structural integrity. This design reduces dynamic loads and extends belt lifespan. The gripping component is manufactured using a cylinder sector approach, where the edges are radially bent inward to distribute stress more evenly.(Figure 2) Finite Element Analysis (FEA) was conducted to evaluate the structural stability of the new design under load conditions.

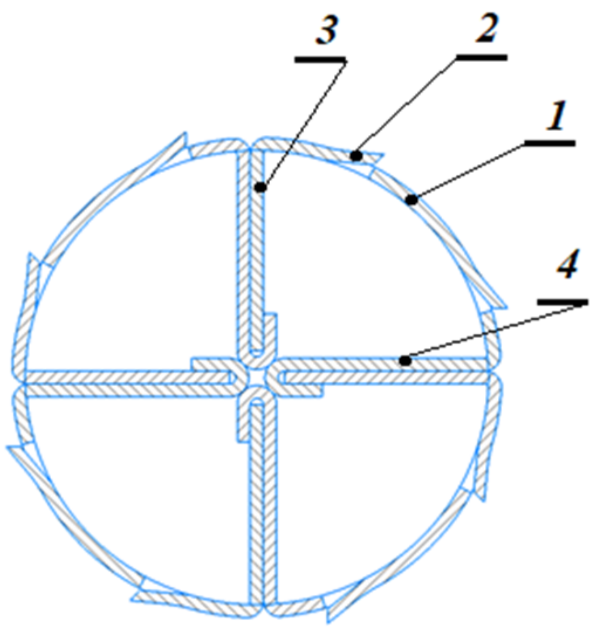

Figure 2. Cross-section of the spindle's gripping part: 1 - Cylinder sector; 2 - Tooth; 3,4 - Radially bent edges.

To manufacture the structure, a segment forming the cylinder sector is first cut from a sheet of PT-65G steel with a specified thickness, and teeth are machined on it (Figure 3).

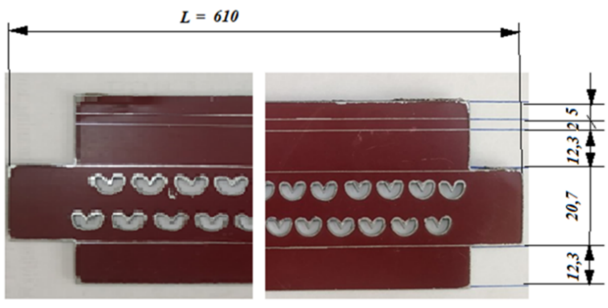

Figure 3. Geometry of cylinder sector elements

Then, in a special mold, the toothed part is bent into a 1/4 cylinder segment, and its edges are directed inward and bent (Figure 4).

Manufacturing Process. The following steps

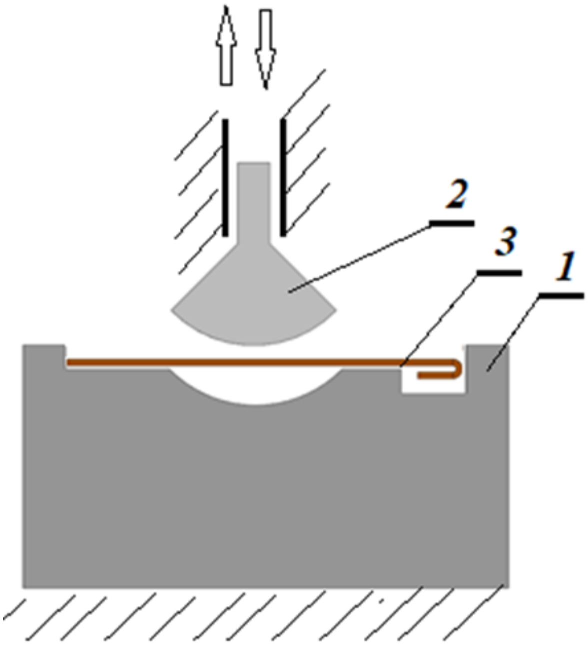

Figure 4. Bending device: 1 - Die; 2 - Punch; 3 - Cylinder sector segment.

outline the production of the lightweight spindle:

1. Cutting steel sheet (grade 65G) using a BODOR A3 laser cutter.

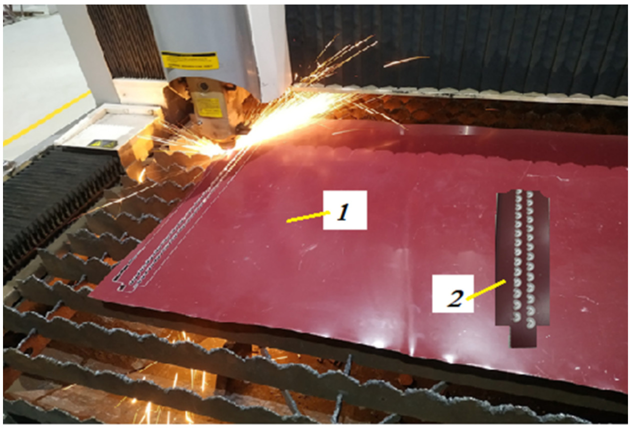

Figure 5. BODOR A3 laser cutting machine 1 - Softened steel sheet of grade 65G; 2 - Tooth-cut segment.

2. The dimensions are determined for bending the cut pieces. (Figure 3).

3. Bending the cut parts with WS-2x1300 bending equipment.

4. Then, 12.3 mm sections are bent using the sheet bending machine (Figure 7).

Figure 6. WS-2x1300 sheet bending machine

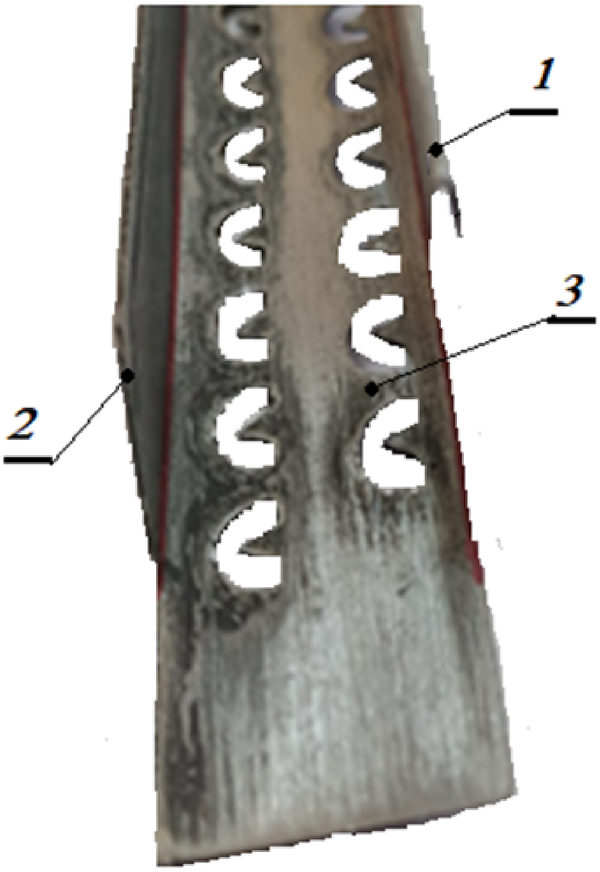

Figure 7. Bent edges condition. 1, 2 - Radially bent edges inward; 3 - Bendable cylinder sector.

5. Further processing to form the spindle's final shape using precision machining techniques.

6. Assembling and heat-treating the spindle in a mold to improve hardness and wear resistance.

7. Installing the drive roller and support bearings, ensuring alignment and smooth operation.

8. Conducting performance tests under simulated operational conditions.

In general, the spindle will have the following appearance (Figure 8).

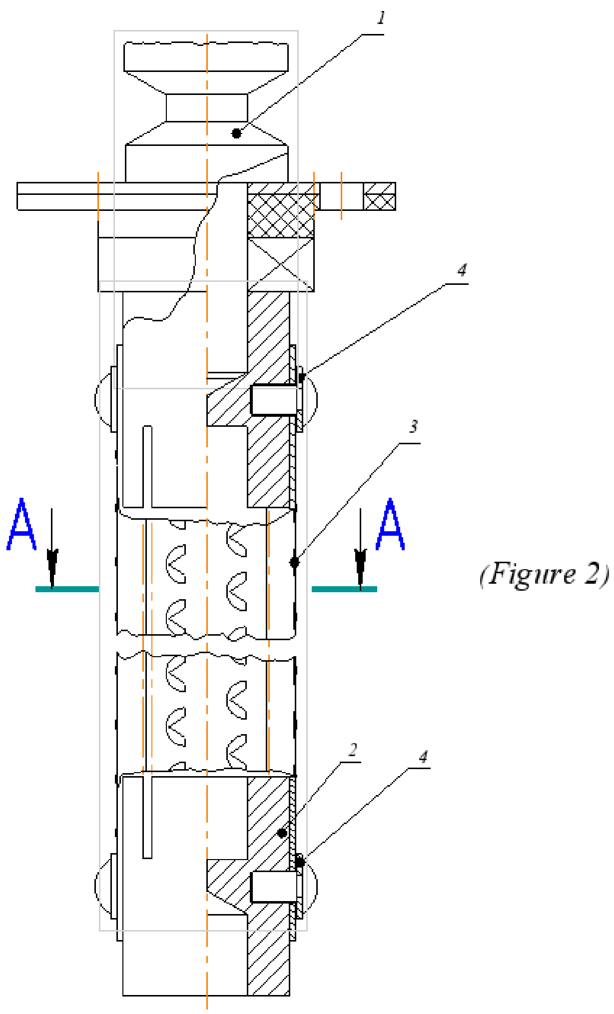

Figure 8. General appearance of the spindle. 1 - Drive roller; 2 - Lower part of the spindle; 3 - Lightweight gripping part; 4 - Connecting ring.

Results

The newly designed spindle weighs 1029 g, which is significantly lighter than existing models. Reduction in spindle weight resulted in a 15% decrease in mechanical stress on the drive system, improving longevity. Weight comparison with conventional spindles:

The weight reduction improves durability and efficiency. Performance tests demonstrated a 20% increase in spindle lifespan due to lower stress on moving parts.

Spindle Type	Average Weight (g)	Reduction (%)
Solid metal (mass-produced)	1410	27%
Screw-type (mass-produced)	1810	43%
Shelled (tested)	1710	40%
Shelled with free core (tested)	1730	41%
Lightweight (proposed)	1029	–

The lightweight spindle's reduced mass decreases wear and tear on the planetary drive system. The spindle's modular construction allows for part replacement and customization, improving maintenance efficiency. The study results suggest that the new design could reduce energy consumption by 10% in cotton-picking machines, making them more sustainable. Future research may focus on optimizing material properties through alloy modifications and further testing under real-world conditions. The implementation of advanced coatings to further enhance durability and wear resistance is also a potential area of improvement.

Conclusion

The development of a lightweight spindle for vertical spindle cotton-picking machines significantly reduces mechanical stress, prolongs the lifespan of moving parts, and enhances overall efficiency. The proposed design offers a viable solution for improving machine performance, durability, and sustainability. By integrating new manufacturing technologies and material optimizations, future models can further improve upon these advancements.

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