Remote control device to control the contact uniformity of the brush strippers on the spindle’s surface of the cotton picking apparatus

E Uljayev1*, Sh T Ravutov2, and U M Ubaydullayev1

1Department of Information Processing and Management Systems, Faculty of Electronics and Automation, Tashkent State Technical University named after Islam Karimov, University str. - 2, Almazar district, 100095 Tashkent, Uzbekistan
2Department of Overhead transport systems, Faculty of Machine Construction, Tashkent State Technical University named after Islam Karimov, 2 str. University, Almazar district, 100095 Tashkent, Uzbekistan

*Email: e.uljaev@mail.ru

Abstract. In this paper, the question of implementation remote control of contact uniformity of brush strippers on a spindles surface of the harvest device of the mechanical cotton picker is considered. A brief analysis of known works is carried out and the urgency of the development of a specialized remote control system for the rotation speed of brush strippers and the uniformity of touching the brush strips on the surface of the spindles is substantiated. As a sensing element, it is proposed to use a strain gauge that changes its ohmic resistance when the stripper brush touches the spindle surface. A wireless GSM communication unit is used for remote transmission and reception of information.

1. Introduction

In order to improve the efficiency of brush strippers, the scientists of the Department of Ground Transport Systems and the Institute of Mechanics of the Academy of Sciences proposed to change the design and method of their location. Theoretical analyzes and calculations on the number of revolutions were carried out when placing them with a slope of 70-75°. On experimental cotton picker and on test field conditions, tests and performance of the proposed brush stripper were carried out. The experiments gave positive results, i.e. the productivity of the cotton picker has increased, and the degree of shock and vibration phenomena during the interaction of splinter strips with spindles has significantly decreased [1]. Theoretical and experimental research work has been carried out to improve the quality of bench testing of the parameters of the interaction between the stripper brushes and the spindles of a cotton picking machine [2, 3], as well as to automate the study of the parameters of the interaction between the stripper brushes and the spindles [4]. On the development and control of the rotation speeds of the spindles and brush strippers, many successful practical developments have been carried out that have passed experimental studies in laboratory and field conditions [5].

To study the uniformity (stability) of the rotation speeds of the modernized brush stripper and the productivity of picking raw cotton, it is necessary to study the trajectory of its rotation, the uniformity of the brush touch on the surface of the spindle teeth, the stability of rotation (no vibration), and the
degree of wear of the strippers. Note that in one spindle drum there are two brush strippers, and each of them has six to eight brush strips.

Despite a number of studies carried out, there are currently no specific devices to accurately establish the speed modes of rotation of the brush stripper, to quantify the uniformity of touching the stripper brushes on the surface of the spindles and the degree of wear of the bristles, depending on the speed modes and the intensity of their impact on the surface of the spindles [6-15]. The existing measuring system [2, 4] is based on an old loop oscilloscope. This is all due to the complexity of the control, associated with the difficulty of placing or installing control sensors on rotating brush strippers. All this requires a new approach, the use of new developments and methods for controlling the rotation speeds of the brush stripper and the degrees of contact of the brush strips on the surface of the spindles, which is an urgent issue for the designers of the design of both new spindles and brush removals.

2. Methods

In this work, we have proposed an automated microprocessor-based device for controlling the rotation speeds of the modernized brush stripper and the degree of brush contact on the surface of the spindles. Since, according to the design of the brush drum, six, eight brush strips are rigidly placed in one drum and the rotation speed is sufficiently high (1600 ÷ 1750 rpm), it is sufficient to control the rotation speed of the drum as a solid cylinder, and the stability of rotation and the degree of contact and wear of each brush the planks must be monitored separately.

Thus, in total, it is necessary to control the rotation speeds of three stripper rolls, the degree of contact and rotation stability of 12 stripper rolls in the apparatus. The positions of the brush strippers on the picking machine are shown in Figure 1.

![Figure 1. The positions of the brush strippers on the cleaning machine](image)

The purpose of the work is to control the rotation speed of the stripper rolls and the degrees of contact of the SCB on the teeth (surface) of the spindles. Figure 2 shows a functional diagram of one version of an automated device for monitoring the listed parameters for one brush drum. The transmitting part of the device consists of the following blocks: PM - permanent magnet; HS-Hall-effect sensor; 1SG-6SG - strain gauges; 1OA-6OA-operational amplifiers; MC -microcontroller. The receiving part of the device consists of the following blocks: Microcomputer-tablet or mobile phone with built-in Android software, MC Disp-built-in multi-channel display, MSDSU-mode selecting and device starting unit, as well as an alarm unit (AU). The transmitting and receiving parts of the device are powered from a rechargeable battery up to 5V.
Figure 2. Remote control system for the rotation speed of the brush bar and their degree of contact on the surface of the spindles of the cotton picker apparatus

The purpose of the blocks and the principle of operation of the transmitting part of the device: A permanent magnet and a Hall sensor are designed to give a signal about the start of rotation of the stripper roll; 1SG-6SG are strain gauge sensors connected to the inputs of the corresponding operational amplifiers and are converters of information about the degree of contact of the brush strippers by the value of resistance proportional to the degree of contact of the surfaces of the corresponding spindles. Operational amplifiers 1OA-6OA convert the values of the change in resistance to proportional voltages and they are fed to the analog inputs of the microcontroller (MC). The MC receives the incoming analog information according to a given algorithm, processes them, and the processed information characterizing the degrees of contact of each brush stripper is written to the corresponding memory registers. After that, according to the set time or at the request of the receiving part of the MC, in turn, in the form of a binary code, the stored information is given in memory to the data reception part.

The principle of operation of the receiving part of the device is as follows: information transmitted from the data transmission part is received by the data reception part and, after filtering and processing, transfers them to the input of a microcomputer (Tablet, mobile telephone). The information is processed on the microcomputer according to the established program. The processed information characterizing the degrees of contacts the brush strip on the corresponding spindles is issued in the form of a decimal code or graphically on the corresponding 1-6 rows of the multichannel display. The operator, knowing the speeds of rotation of the brush drum or brush strips and the degrees of contact of the brush strip on the corresponding spindles, evaluates the quality of manufacture and mounting of the brush strip on the stripper rolls and takes appropriate measures.

With the MSDSU block for selecting the brush strips and starting the device, it selects the desired brush strip and starts the device. The alarm unit notifies the operator of the normal operation or emergency state of the device.

A copper wire placed along the extension of the brush strips by a special mounting method was chosen as a strain gauge sensor. The elastic properties of the wire are close to that of the removable drum bristles. When the degree of contact of the copper bristles of the strips on the surface of the spindle
Changes, the ohmic resistance of the wire sensor will change from minimum to maximum, the lower the degree of contact, the greater the ohmic resistance.

Resistive-strain sensors are used to measure deformations and mechanical stresses in machine parts and mechanisms. They can also be used to measure other mechanical quantities (pressure, vibration, acceleration, etc.) that are previously converted into deformation.

3. Results and Discussion

The principle of operation of a wire strain gauge is based on the change in the active resistance of the wire during its deformation. The change in the active resistance of the wire occurs for two reasons: first, the geometric dimensions of the wire change (length \( l \), section \( s \)); secondly, upon deformation, the resistivity \( \rho \) of the wire material changes, these values determine the active resistance of the wire \( R = \frac{\rho l}{s} \).

For example, consider a strain gauge wire (Figure 3) of length \( l \), radius \( r \), cross section \( s = \pi r^2 \) and volume \( V = \pi r^2 l \), which, when deformed (stretched) under the influence of force \( F \), gains an elongation \( dl \) and a decrease in radius \( dr \). Consequently, the new wire volume

\[
V + dV = \pi(r - dr)^2(l + dl)
\]

Neglecting infinitesimal higher orders [of the form \((dr)^2, drdl\)], we obtain

\[
V + dV \approx \pi r^2 + \pi r^2 dl - 2\pi rldl
\]

whence the volume increment

\[
dV = \pi r^2 dl - 2\pi rldl
\]  \hspace{1cm} (1)

We transform equation (1) by multiplying and dividing the subtracted by \( rdl \) and replacing \( \pi r^2 \) with \( s \):

\[
dV = sdl - 2\pi r \frac{rdl}{rdl} = sdl - 2sd\left(1 - 2 \frac{dr}{dl} \right) = sdl(1 - 2\mu),
\]

where \( \mu = 2 \frac{dr}{dl} \) - Poisson's ratio, which characterizes the change in the dimensions of the wire under tension; for metals \( \mu = 0.24 \div 0.5 \). If the material did not change its volume under tension, then \( dV = 0 \) and \( \mu = 0.5 \).

![Figure 3](image-url)

**Figure 3.** Changes in the dimension of the strain gauge wire sensor under tension and deformation

Thus, real metals change their volume, and therefore, they also undergo intrastructural changes: the density of the material and its resistivity obviously change.

The resistance of a strain gauge also changes with temperature. To reduce the temperature error of the strain gauge, its material must have a high sensitivity at a low temperature coefficient of expansion and a low value of thermo-EMF in contact with copper connecting wires.

During the control of the degree of contact of the brush strip along the longitudinal length \( L \) (mm) of the spindle teeth, depending on the degree of contact on the spindle sections, the resistance of the
strain gage changes in different ways. Figure 4 shows the temporal characteristics reflecting the
dependence of the change in the output voltage of the strain gauge on the force of impacts (touching)
of the brush stripper on the spindle surface.

\[ U_{\text{out}} = R_t \cdot t / k \cdot F \cdot \cos(\omega + \omega_0) = R_t \cdot t / k_f k_p \cdot F \cdot \cos(2\pi f + \omega_0) \]  

where \( U_{\text{out}} \) – op-amp output (mV); \( R_t \) – strain gage resistance (kΩm); \( t \) – measurement time (sec); \( k_f \) – impact force coefficient of the brush strip; \( k_p \) – total force of impacts of different disturbing coefficients (vibration, knocking, etc.); \( F \) – impact force of the brush stripper (newton); \( \omega \) – angular frequency of rotation of the brush strip (\( \omega = 2\pi f \)); \( \omega_0 \) – initial phase; \( f \) – impact frequency (Hz).

Analyzing the graph of the dependence of the resistance change of the strain gauge on the impact force
degrees of touch) of the brush strip on the spindle surface, the following conclusions can be drawn:
when the brush strip does not touch the spindle surface \( U_{\text{out}} \) has a minimum value; when the brush strip fully touches the surface of the spindle \( U_{\text{out}} \) has a maximum value; Graph 3 shows when the brush bar touches the starting area of the spindle; Graph 4 shows when the brush bar touches the bottom of the spindle; Graph 5 shows when the brush strip touches the surface of the spindle in a sinusoidal manner.

3.1. Design of the board for placement and installation of converters and information transmitter
The size of the board structure corresponds to the size of the head of the brush strip and is made in a
round form from a foil-coated CEM board. A Hall sensor, seven operational amplifiers are placed on
the foil-clad CEM board, the terminals of six wire strain gauges (strain gauges) are connected by
means of a printed circuit diagram to the inputs of the corresponding operational amplifiers, and
the outputs of the operational amplifiers are connected to the corresponding analog inputs of the
microcontroller, the serial output of the MC is connected to the input of the wireless unit GSM
communication. All units of the transmitting part are powered from a 5V flat battery. A copper wire
placed along the extension of the brush strips by a special mounting method was selected as a strain gauge sensor.  

Reminder. At the beginning of the device start-up, a pulse is formed at the output of the Hall sensor, the shape of which is close to rectangular. The output of the Hall sensor by means of the NOA operational amplifier is connected to the discrete input of the MC and is the triggering pulse of the MC. The impulse of the Hall sensor is a warning signal about the beginning of the counting of the MC speed of rotation of the stripper roll (or brush strip), and about the information received about the degree of contact of the first brush strip on the spindle surface. Following the information about the degree of contact of the first brush strip on the brush surface, information about the degree of contact of other brush strips is received in turn at the input of the MC. After the seventh information, the cycle is repeated. Thus, after the set counting cycle, the microcontroller processes the accumulated information of each brush strip and, in the form of a binary code, via wireless communication, transfers it to the receiving panel for further processing. In the receiving panel, the received information is processed according to a given algorithm and is displayed on the built-in digital display in a convenient form for use.

4. Conclusion
The microcomputer displays the processed information, characterizing the degrees of touching the brush strip on the corresponding spindles, in the form of a decimal code or graphically, to a multichannel display. The digital display of information is displayed on dedicated channels of information display, i.e. each information is displayed on its own dedicated channel. For in-depth analysis, information can be transferred to a USB flash drive or via a field communication line to a powerful computer for further processing. Using an intelligent information processing algorithm on a scale graph, you can see the degree of contact with the brush strip on the spindle sections. By analyzing the results obtained on a personal or other computer, the designers can make changes to the design of the brush strips and their placement on the brush drum.

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