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DETERMINATION OF KINEMATIC AND DYNAMIC PARAMETERS IN A COTTON PNEUMOTRANSPORT FAN SHAFT WITH AUTOMATIC CONTROL MECHANISM

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Abstract
Objective. The article describes a simple electrotensometric method of determining the loads of the working bodies of a pneumatic transport device whose energy parameters are controlled for transporting cotton to different distances. As a result of the automatic management of energy indicators, the results of comparing the changes in torque and angular speed values on the air transport fan shaft with the existing system were analyzed. Graphs of the dependence of the torque value on the pneumotransport shaft on the work performance and the dependence of the average value of the angular speed of the pneumotransport shaft on the technological resistance were obtained.
Methods. It should be noted that in recent years in cotton ginning enterprises, the use of pneumatic transport system engines with an inverter device has become a demand of the times.
Results. Experimental studies of determining the kinematic and dynamic parameters of the pneumotransport fan shaft moving through the proposed system were carried out using the electrical strain gauge method.
Conclusion. According to the above research and analysis results, it is possible to reduce energy consumption by 10% by applying inverter devices to the currently used pneumotransport system and adjusting the kinematic and dynamic parameters of the fan shaft.

Keywords. Cotton, pneumatic transport, fan, technological parameter, strain gauge, inverter, electric motor, photoelectric sensor, strain sensor; torque converter, microcontroller, computer, torque, angular speed, amplitude, technological resistance.

Introduction

In the transportation of cotton within the enterprise, suction-type pneumatic transport is mainly used [1]. The advantage of this pneumatic transport equipment is that it is possible to easily change the working air pipe system depending on the location of the storage areas of cotton ginning enterprises, and its length can be extended by connecting additional air pipes to the initial air pipes.

When transporting cotton from different distances, the required air pressure and air speed are provided by the throttle, by changing the position of its blades. There are several ways to control the parameters of the pneumatic transport system in industries:

- control of air pressure and consumption using a throttle;
- changing the direction of the airflow with the help of directional paddles;
- changing the number of rotations of the fan shaft using a gearbox;
- changing the number of revolutions of the electric motor rotor using a frequency converter (inverter).

Today, several scientific researches aimed at the development of modern, automatically adjusted transport devices for all branches of mechanical engineering, taking into account all processes, are being carried out. At the same time, there is also a large amount of research aimed at increasing the performance of the machines by improving the construction of the transport machines that are used in enterprises and equipping them with modern devices.

Methods

It should be noted that in recent years in cotton ginning enterprises, the use of pneumatic transport system engines with an inverter device has become a demand of the times. Modern inverter devices have the possibility of automatic management and control, as well as features of maintaining the optimal values of various technical parameters. As a result of the conducted research, a mechatronic system for controlling the energy indicators of cotton pneumatic transport was developed [2-7]. Figure 1 shows a pneumotransport scheme equipped with an inverter operating in a mechatronic system [12].

In the process of work, the pneumotransporter is connected to the power source through an inverter. The inverter supplies the fan with a gradually increasing electric current. The nominal (maximum) number of rotations of the fan is reached within 15-20 seconds after connecting to the plug.

It is possible to determine the values of torque and angular velocity on the shaft of a pneumotransport fan moving with the proposed system and to determine the efficiency indicators of the proposed system by comparing it with the existing system.

Methodology of experimental determination of kinematic and dynamic parameters of cotton pneumotransport fan shaft. Based on the conducted analytical research, the kinematic and dynamic parameters of the pneumotransport fan shaft were determined using the electrotensometry method. It is important to determine the following parameters of the pneumatic transport fan shaft equipped with the proposed inventor [8]:

determining the change in torque values on the drive shaft;

determination of changes in angular velocity values of the drive shaft.

The electrical strain gauge method was used to determine the kinematic and dynamic parameters mentioned above. A strain gauge is considered a device for measuring deformations, and it corresponds to the content of research studies. Today, types of strain gauges are widespread and are divided into different classes according to their characteristics. The strain gauge performs the function of measuring the values of deformation formed on the specified surface of the studied detail. The length of the surface of the part whose deformation is to be measured is determined according to the base of the strain gauge. According to the base of the strain gauge, the short base is 5 mm, the middle base is 20 mm, and the long base is 30 mm. No strain gauge detects point deformation.

The data transmitted through the strain gauge can be transmitted directly to the equipment block through a wire (current collector) or over a long distance through electromagnetic signals. Tensometry methods based on the above characteristics are mechanical; pneumatic; acoustic; optical; and electricity; divided into combined groups.

The above-mentioned methods are divided into sub-methods. For example, the method of electrical strain gauge is divided into strain gauges that work according to the characteristics of resistance, inductance, capacitance, photo electricity, and piezoelectricity. Any strain gauge must have a sufficiently high sensitivity and accuracy. Also, the strain gauge should be easy and convenient to install and should not negatively affect the accuracy of the results of dynamic deformations.

Results

Experimental studies of determining the kinematic and dynamic parameters of the pneumotransport fan shaft moving through the proposed system were carried out using the electrical strain gauge method.

Electrotensometric measurement of deformations is based on the characteristics of the dependence of electrical resistance of conductors on deformation. This method was proposed in 1856 by William Thomson, a physicist and mechanical scientist (Great Britain, Scotland). In 1881, the Russian physicist Orest Danilovich Hvolson proved that stretching and compressing metal wires not only their geometric dimensions but also their electrical resistance. Scientists such as Percy Williams Bridgeman (1882-1961 USA), and Howard Simmons (1929-1997 USA) made a great contribution to the development of the electrical strain gauge method.

The specific change in electrical resistance under the influence of stretching and compressive deformation of a current-carrying material (wire) is called the piezoresistive effect (tension effect). The electrical resistance of the wire is determined by the following expression:

$$R = \rho \frac{l}{F} \quad (1)$$

here, $R -$ resistance of the conducting wire (Om); $\rho -$ the specific resistance of the wire (om $\times mm^2$/m); $l -$ wire length m, $F -$the cross−sectional surface of the wire mm^2).

Wired tensor sensors were used to determine torque values on the pneumotransport shaft. Wire tensor resistors (Fig. 2) have the form of a rectangular ring-shaped grid 1 and are connected to copper or aluminum wire 3 by brazing or welding. The wire fence is covered with flat paper or film 2 using glue.

To determine the kinematic and dynamic parameters of the proposed chain transmissions, wire tensor resistors with a central base of 10 mm resistance R=200 Om was used. Tensor resistors were attached to the leading and driven shafts in the bridge method.

Because the resistance of the tensor resistor is relatively small, they are attached to the desired surfaces in various schemes. The bridge connection is shown below (Fig. 3.16).

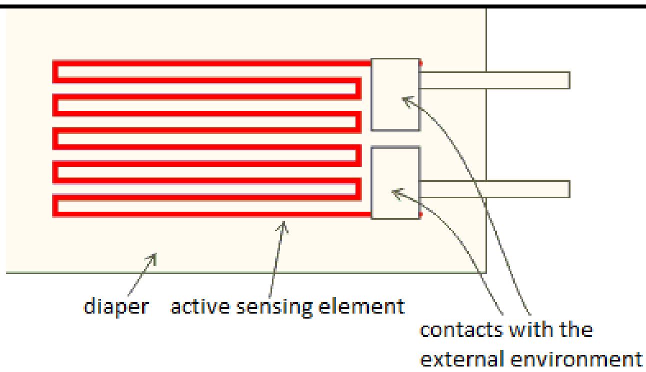

Figure 1. Schematic of a wire tensor resistor

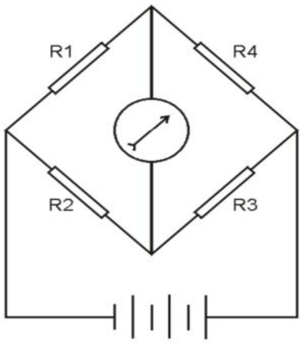

Figure 2. Bridge scheme of placing strain gauges

A bridge scheme was used to determine the change in torque value of the proposed pneumotransport system driver shaft. To calibrate the signals coming from the strain gauges and to describe their value in mechanical units, it is calibrated. The calibration graph is shown in the figure below.

Laws of change of values of torque and angular speed on the pneumatic fan shaft

The proposed inverter engine was fixed in place of the pneumatic transport system engine that was in working condition at the manufacturing plant. Devices for determining torque and angular velocity values were installed on the VS fan shaft. Figure 4 shows the electrotensometric scheme for determining the kinematic and dynamic parameters of the fan shaft. Based on the electrotensometric scheme, experimental studies were conducted at the Kosonsoy cotton ginning enterprise (Fig. 3).

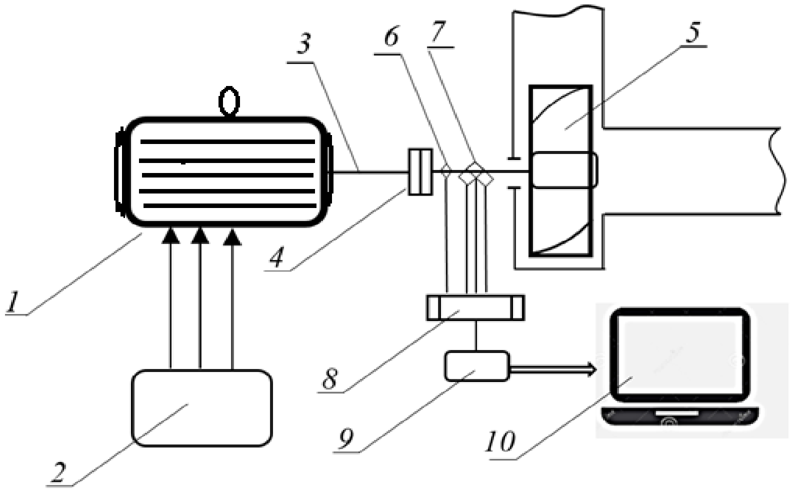

Figure 3. Electrotensometric scheme for determining the kinematic and dynamic parameters of the fan shaft. Here: 1 - an electric motor; 2 – INVT 380V type inverter; 3 – electric motor shaft; 4 – clutch; 5 - fan, 6 - laser photoelectric sensor-3pin IK; 7 - strain gauge; 8 - current collector; 9 - Arduino Nano V3.0, CH340 microcontroller, 10 – computer

The torque and rotational speed of the fan shaft driven by the proposed procedure were determined in the following order:

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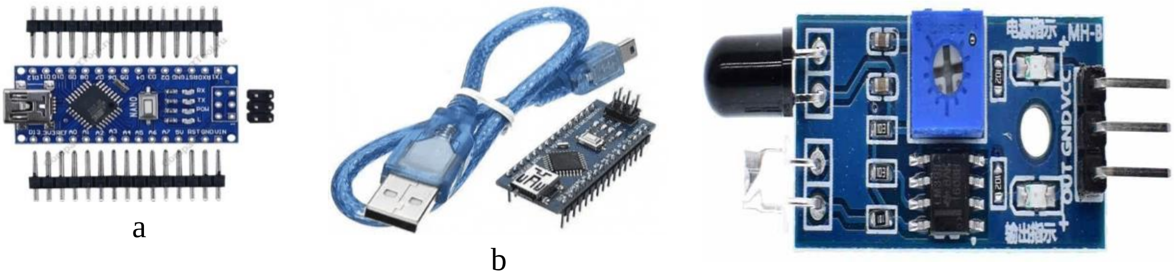
It is equipped with electric motor 1 (N=75 kW, n=1500 rpm), INVT 380V type inverter 2. The drive from shaft 3 of the electric motor 1 is transmitted to the shaft of fan 5 through valve coupling 4. Deformation occurs as a result of the effect of the technological resistance force corresponding to the value of the weight of the cotton transported on the fan shaft 5. The resulting deformation value is transmitted to the current collector 8 through strain gauges 7 attached to the shaft in a bridge manner, and from the current collector to Arduino Nano V3.0, CH340 microcontroller 9. It also transmits signals to the Arduino Nano V3.0CH340 microcontroller 9 through the laser photoelectric sensor-3pin IK 6, which detects the angular speed change on the fan shaft. The signals determining torque and angular velocity values obtained in parallel are transmitted to the computer 10 through the microcontroller 9. Data is processed on a computer based on a program that works by the Arduino Nano V3.0CH340 microcontroller (Fig. 6).



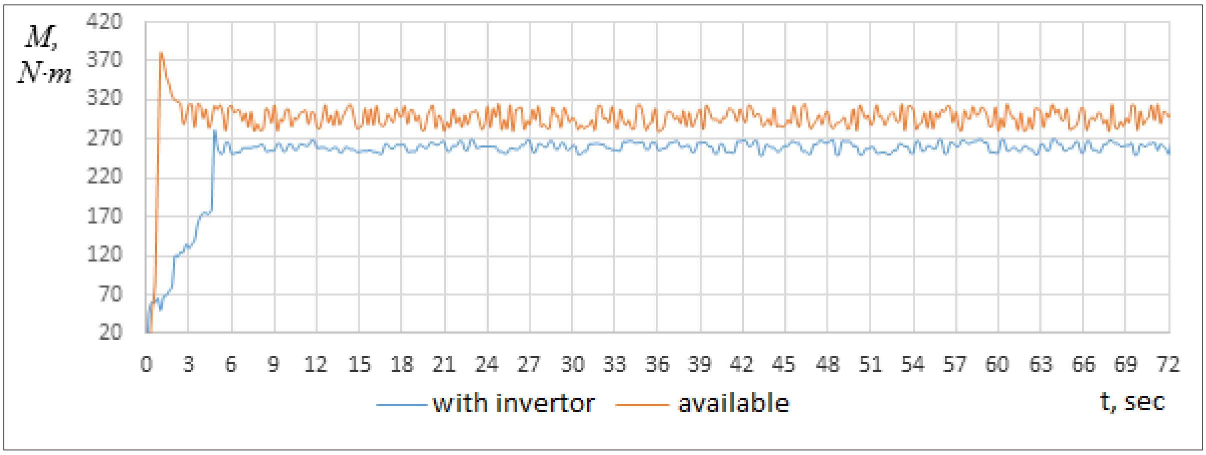
a b c

Figure 3. *a*-Arduino Nano V3.0, CH340 microcontroller,
b- ATmega328 with USB cable, A module working in cooperation with the ARDUINO program, c- laser photoelectric sensor-3pin IK

Analysis of the obtained results

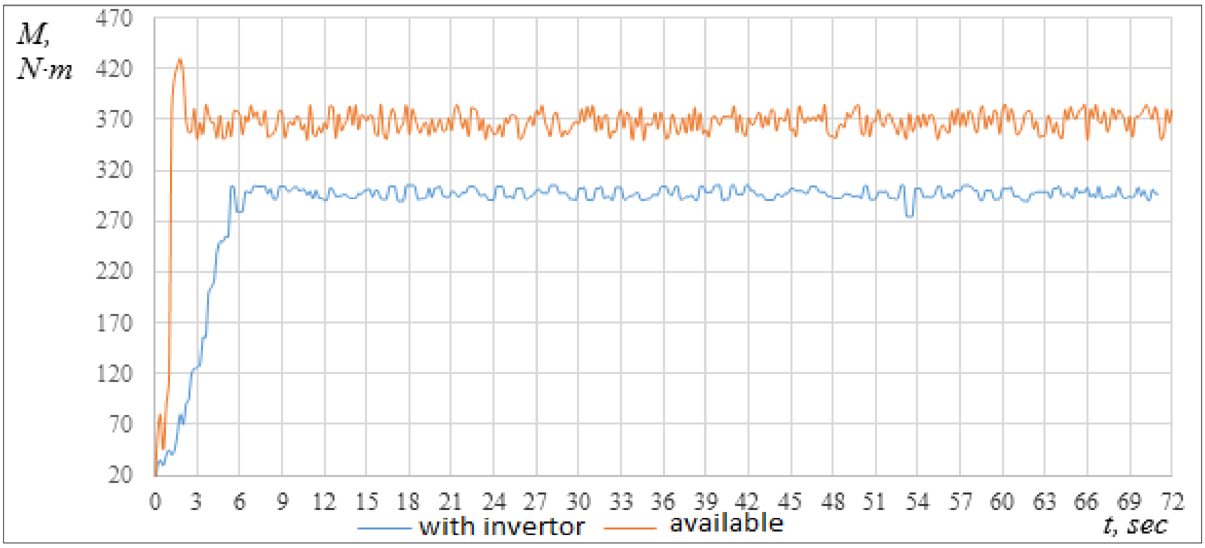
The graphs obtained according to the results of the experiment are detailed below. The values of the torque and rotational frequency of the fan shaft were obtained when the driving shaft rotation frequency was 1450 rev/min, and the technological resistance (according to the amount of transported cotton) was 300, 350, and 400 N·m, respectively. Each of the results of the experimental studies was studied about the case of an existing electric motor, and comparison graphs were obtained. Fig. 4 depicts graphs of the laws of change of the torque on the working shaft of the pneumotransport fan at the three different technological resistances mentioned above. The analysis of the obtained oscillograms shows that when the pneumotransport is moving through the electric motor in the existing system when the work efficiency is 8t/h, we can see that the load on the fan shaft, that is, the value of the torque changes in the range of (283÷313)N·m. Also, at the same technological loading (8t/hour), when the inverter engine was introduced, the range of the torque value on the fan shaft was (260÷280)N·m.

In Fig. 4, b, when the pneumatic transport productivity is 10t/h, the range of torque value on the fan shaft driven by the existing engine is (350÷382)N·m, when the pneumatic transport is driven by an inverter motor we can see that the range of torque on the fan shaft is (279÷300)N·m.

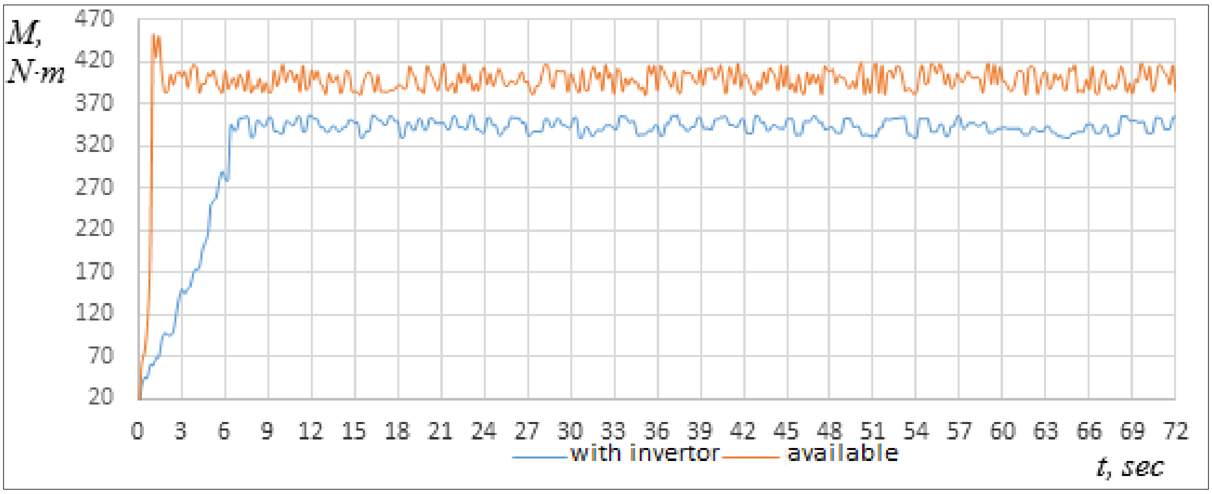


a) technological resistance 300 $N \cdot m$

b)



b) technological resistance 350 $N \cdot m$



c) technological resistance 400 $N \cdot m$

Figure 4. The graphs of the torque change on the fan shaft in the case of n_1=1450 rpm, As a result of the application of the proposed inverter engine.

In Fig. 4, c, when the productivity is 12t/h, the torque value of the torque on the shaft of the pneumatic transport fan with the existing drive is (389÷418)N·m, while this value is applied to the inverter drive (331 ÷351)N·m.

Conclusion

According to the above research and analysis results, it is possible to reduce energy consumption by 10% by applying inverter devices to the currently used pneumotransport system and adjusting the kinematic and dynamic parameters of the fan shaft. There is an opportunity to further increase energy efficiency through the proposed system in different transportation of cotton. The kinematic and dynamic parameters are at the required value by the technological resistance of the fan shaft when the pneumatic transport is controlled through the proposed system, based on the results of experimental studies. If it is determined that the torque and angular velocity values of the fan shaft driven by the proposed system can be reduced by 15% on average compared to the existing system, the average value of the amplitude change of the torque when the productivity is 10t/h It was determined to be less than 21.01%.

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