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POTENTIAL APPLICATIONS OF ENCODERS

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POTENTIAL APPLICATIONS OF ENCODERS TO CONTROL THE TURNING ANGLE OF A TRACTOR'S DRIVING WHEEL

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Abstract: *This article explores the applicability of diverse sensor types—such as optical, magnetic incremental encoder and potentiometric sensors—for controlling the turning angle of tractor steering wheels, specifically addressing the control challenges faced by semi-mounted cotton pickers. The discussion encompasses fundamental principles, operational aspects, advantages, and limitations of turning angle sensors prevalent in the industry. Emphasizing advancements in sensor technology, the article recommends sensor options for controlling the steering wheel's turning angle, crucial for enhanced maneuverability and operational efficiency of semi-mounted cotton pickers. Various sensor types, including optical and magnetic encoders and potentiometers, are evaluated for their suitability in this context. Optical encoders, for instance, are detailed regarding their ability to convert rotational movements into digital signals and their classification into incremental and absolute types. The merits and limitations of each sensor type—such as the narrow control range of incremental encoders and the advantages of absolute encoders—are systematically analyzed. Furthermore, the potential use of magnetic encoders, based on the Hall effect, is explored, highlighting their reliability and suitability for controlling rotation speeds. The article concludes by recommending sensor options based on their effectiveness in converting turning angles into electrical signals, offering insights into optimal choices for controlling the tractor's steering wheel angle in cotton pickers.*

Keywords: *optical encoder, absolute encoder, magnetic encoder, potentiometer, turning angle control, cotton picker, sensor technology.*

Annotatsiya: *Ushbu maqolada traktor boshqaruv g'ildiragining burilish burchagini nazorat qilish uchun optik, magnit inkremental enkoderlar va potensiometrik datchiklar kabi turli xil datchiklardan foydalanish imkoniyati, xususan, yarim osma paxta terish mashinalari parmetrlarini nazorat qilish muammolarini hal qilish o'rganilgan. Muhokama sanoatda keng tarqalgan burilish burchagi datchiklarining asosiy tamoyillari, foydalanaolish jihatlari, afzalliklari va kamchiliklarini o'z ichiga olgan. Datchik texnologiyasidagi yutuqlarni ta'kidlagan holda, maqolada boshqaruv g'ildiragining burilish burchagini nazorat qilish uchun datchik variantlari tavsiya etilgan, bu esa yarim osma paxta terish mashinalarining manevrchanligi va ish samaradorligini oshirish uchun juda muhimdir. Har xil turdagi datchiklar, shu jumladan optik va magnit enkoderlar va potensiometrlar ushbu masalani hal qilishda mos kelishligi baholangan. Masalan, optik enkoderlar burilish harakatlarini raqamli signallarga aylantirish qobiliyati va ularni inkremental va absolyut turlarga tasniflash bo'yicha batafsil ma'lumot keltirilgan. Har bir datchik turining afzalliklari va kamchiliklari, masalan, inkremental enkoderlarning tor nazorat diapazoni va absolyut enkoderlarning afzalliklari - tizimli ravishda tahlil qilingan. Bundan tashqari, Xoll effektiga asoslangan magnit enkoderlarning qo'llanilishi mumkin bo'lagan sohalar o'rganilib, ularning ishonchliligi va burchak tezliklarni nazorat qilishda samarali ekanligi keltirilgan. Maqolaning xulosa qismida burilish burchaklarini elektr signallariga samarali aylantirishi mumkin bo'lgan datchik turlari tavsiya qilingan hamda paxta terish mashinalarida traktor boshqarish g'aldiragining burilish burchagini nazorat qilish uchun datchiklarning optimal variantlari keltirilgan.*

Tayanch so'zlar: *optik enkoder, absolyut enkoder, magnit enkoder, potensiometr, burilish burchagini nazorat qilish, paxta terish mashinasi, datchik texnologiyasi.*

Аннотация: *В этой статье исследуется применимость различных типов датчиков, таких как оптические, магнитные инкрементальные энкодеры и потенциометрические датчики, для контроля угла поворота направляющих колес трактора, в частности, для решения проблем контроля, с которыми сталкиваются полунавесные хлопкоуборочные машины. Обсуждение охватывает фундаментальные принципы, эксплуатационные аспекты, преимущества и ограничения датчиков угла поворота, распространенных в отрасли.*

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Подчеркивая достижения в области сенсорных технологий, в статье рекомендован варианты датчиков для контроля угла поворота направляющих колес, что имеет решающее значение для повышения маневренности и эффективности работы полунавесных хлопкоуборочных машин. Различные типы датчиков, включая оптические и магнитные энкодеры и потенциометры, оцениваются на предмет их пригодности в этом контексте. Например, оптические энкодеры были подробно описаны в отношении их способности преобразовывать вращательные движения в цифровые сигналы, и они были разделены на инкрементальные и абсолютные типы. Достоинства и ограничения каждого типа датчиков, такие как узкий диапазон регулирования инкрементных энкодеров и преимущества абсолютных энкодеров, были систематически проанализированы. Кроме того, было изучено потенциальное использование магнитных энкодеров, основанных на эффекте Холла, что подчеркнуло их надежность и пригодность для управления скоростью вращения. В заключение статьи рекомендованы варианты датчиков, основанные на их эффективности в преобразовании углов поворота в электрические сигналы, а также предложено понимание оптимальных вариантов управления углом поворота ведущего колеса трактора в хлопкоуборочных машинах.

Ключевые слова: *оптический энкодер, абсолютный энкодер, магнитный энкодер, потенциометр, контроль угла поворота, хлопкоуборочная машина, технология датчиков.*

Introduction

Semi-mounted cotton pickers have their harvesting apparatus and steering wheels positioned behind the driver's cab, which makes it difficult for the operator to visually monitor its operation. This also results in reduced productivity and agricultural performance of the machine as it complicates maneuvering and turning, as well as unloading the collected crop into a trolley. To address this issue, several researchers have conducted studies on developing an automated device that can control the turning angle of the steering wheel of semi-mounted cotton pickers, which improves the machine's controllability under these challenging conditions[1-6].

Several techniques and tools have been created to visually monitor the turning angle of tractors and agricultural machines' steering wheels, and these have been developed up until now [7-10].

The turning angle of steering wheels on semi-mounted cotton pickers can be controlled automatically using different types of sensors, including inductive, potentiometric, photoelectric, Hall sensors, and guide pointer methods. This article will discuss the latest advancements in science and technology, such as various types of sensors that can be used to control the turning angle of shafts, position of steering wheels on mobile machines, and other units. Potentiometric sensors and encoders based on physical and electrophysical principles are commonly used for monitoring these parameters[11-13, 8].

Let us consider the features of operation (construction) and control of the position of the driving wheel of a semi-mounted cotton picker. For cotton pickers brand XN-1.8, the steering wheel is located behind the driver's cab. This placement makes it difficult to visually control its work and complicates the controllability of the machine during turns and arrivals by the machine operator. Since the cotton fields are divided into areas (the field run is about 300-400 m) and the cotton plants are planted linearly along the beds, and therefore, during processing and harvesting, the turns of the driving wheel of the cotton picker (to the left and right sides) are carried out at small angles (from 0 to 20 degrees) at low speed. However, during turns, transitions to the next beds, the turns of the drive wheel of the cotton picker are carried out at large angles (from 0 to 90°) at high speed. Therefore, the sensitivity (response), linearity and hysteresis loop and conversion ranges of the selected rotation angle sensors must satisfy the set requirements [14, 15].

Classification, principles of construction and operation of encoders are widely covered in [16]. According to the principle of construction, encoders are made in various versions. Among the options, encoders built on an optical and magnetic basis are widely used.

Research Methods and the Received Results

Analysis of the possibilities of using optical encoders to control the turning angle of the steering wheel of a cotton picker.

Optical encoders can be used to convert the linear or rotational movement of a shaft mounted on a cotton picker's guide wheel into a binary digital signal. Physically, the encoder is a device whose shaft is connected to the rotating part of the object under study. In this case, the moving part of the encoder is mechanically connected to the cotton picker's steering wheel shaft, which provides electronic control of the wheel angle. The base of the encoder (fixed part) is installed on the fixed part - the housing of the rear drive wheel of the machine[8].

In this case, an optical encoder shaft is installed on the control shaft of the steering wheel of the cotton picker, which has a disk with interruption windows around the perimeter, opposite which an LED and a phototransistor are placed, ensuring the formation of

an output signal in the form of a sequence of rectangular pulses with a frequency proportional to both the number of interruption windows and the speed rotation of the disk/shaft. The number of pulses indicates the rotation angle of the drive wheel of the cotton picker. It should be noted that optical encoders are available in the form of incremental and absolute encoders.

Incremental encoders have an interrupt disk with many windows of the same size on the main radius and two readout optocouplers, which allows fixing both the angle of rotation and the direction of rotation of the shaft. On the auxiliary radius of the disk there is a single interrupt window and the corresponding optocoupler, which determine the initial position (reference point) [8, 16].

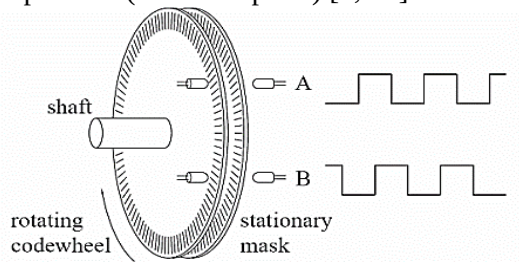


Fig.1. General working principle of an incremental encoder

The main components of an incremental encoder are: a rotating disk (encoding disk) with lines or slots; light source and optical sensor (receiver) (Fig.1).

In this case, the rotating disk with slots interrupts the light beam to the optical sensor and at the output of the optical sensor generates successive pulses, the number of which corresponds to the angle of rotation of the driving wheel of the cotton picker.

The encoder disc converts the turning angle (displacement) into a digital form of the values of the angular displacements of the shaft. A geometric image of a digital code is applied to the coding disk. Depending on the code removal method, the geometric image of the code can be composed of electrically conductive and non-conductive, transparent and opaque, magnetic and non-magnetic sections.

In table 1 shown all possible binary codes formulated by means of a 4-bit encoding disk. To encode the turning angle of a 4-bit encoding disk, four light sources and a photoelectric sensor are required, installed opposite each other. At the outputs of the photo sensors, parallel codes are formed corresponding to the angle of rotation of the wheel (shaft).

Table 1

4-bit coded disk coding table (Gray code)

Decimal code	Gray code	Decimal code	Gray code
0	0000	8	1100
1	0001	9	1101
2	0011	10	1111
3	0010	11	1110
4	0110	12	1010
5	0111	13	1011
6	0101	14	1001
7	0100	15	1000

Since the steering wheel of the cotton picker turns relative to the central axis to the left or right side, and therefore, due to the above and other shortcomings, the considered coding disk cannot be used to solve the problem.

To control the left and right rotations about the axis, you can use widely used encoding discs with binary code varieties, eliminating the occurrence of the above errors. These codes include the so-called Barker code and reflex code (Grey code), which are generated by the consequence of an encoder disk, however, having a single sensor cannot indicate the direction of rotation. To determine the direction of rotation of the shaft or wheel, it is necessary to add a second source-receiver pair, 90 degrees out of phase from the first [17].

The last disadvantage of the considered sensor also limits its use to control the turning angle of the steering wheel of the cotton picker. Note that such sensors (systems) that determine the relative rotation of the disk cannot measure the absolute angular position.

The best option among the considered encoders is the absolute encoder (Fig.2.). It has an interrupt disk with concentric windows at different radii, the relative sizes of which are determined by the binary code, and which are read simultaneously. This design of the encoder disk gives a coded output signal for each angular position in the form of a Gray code or a binary code.

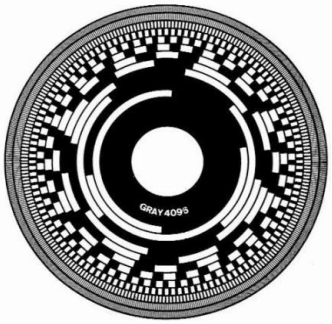


Fig.2. General view of the encoding disc gray code and binary code.

Fig.3. General view of the absolute encoder

This coding method makes it possible to obtain data on the instantaneous position of the shaft, the position of the wheels without a digital counter or return to the initial position, since the output has a multi-bit coded word. Figure 3 shows a general view of the absolute encoder, which is easy to fit on the rotating shaft of the steering wheel of the cotton picker.

Analysis of the possibility of using magnetic encoders to control the angle of rotation of the driving wheel of the tractor

In a magnetic encoder, the conversion of the angular displacement of the shaft into an electrical signal is implemented contactlessly based on the Hall effect. Structurally, the magnetic encoder is built on the basis of a round-pole movable permanent magnet, a microcontroller containing a Hall sensor.

Magnetic encoders are built in two principles: positional, and positional - angular movement. Positional encoders are used as a finite state machine (has a logical signal 1 or 0), position-angle encoders can be used both as a controlled state machine and for measuring rotation speeds and angular position of shafts, wheels or other parts of rotating mechanisms.

The design and general view of the magnetic encoder are shown in Fig.4.

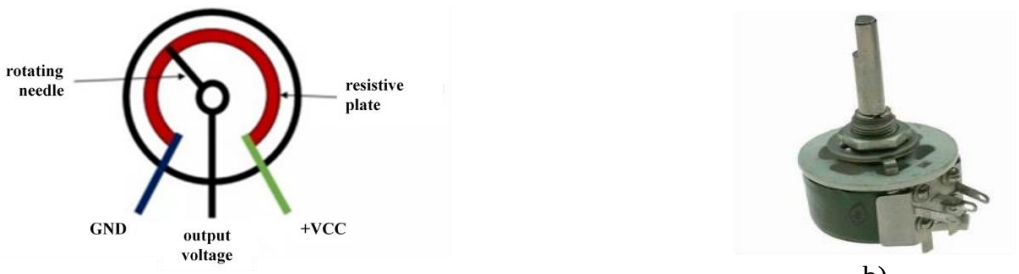
a) b)

Fig.4. ***Design (a) and general view (b) of a magnetic encoder***

When the poles of a permanent magnet rotate over a chip with a Hall sensor, the variable magnetic induction vector induces a Hall voltage containing information about the instantaneous value of the shaft rotation angle. The microcontroller provides a fast conversion of the Hall voltage into a positioning angle parameter.

Potentiometric sensor to control the angle of the drive wheel of the cotton picker

An analysis of potentiometric sensor construction principles showed that to measure small and slowly changing angles of rotation of the shafts relative to the midpoint (from 0 to 350 ^{0}), it is possible to successfully use sensors built on the basis of circularly rotating potentiometers. In this case, the movable part of the potentiometer is structurally fixed to the rotating rotor (shaft) of the controlled object. The design of a circularly rotating potentiometer and its general view are shown in Fig.5.



a) b)

Fig.5. The design of a circularly rotating potentiometer (a), and its general view (b)

Conclusion

A review and analysis of known sensors and devices for controlling turning angle of the steering wheel of the cotton picker showed that the most effective way to convert the angle of rotation (position) of tractor steering wheel are sensors built on the basis of a potentiometer, optical and magnetic encoders. The potentiometer has the convenience of operation and a wide range of rotation angle conversion (from 2^0 to 350^0 and above).

- Turning angle is easily converted to electrical voltage.

- The output voltage of the sensor without additional conversion is fed to the input of the microcontroller and is processed according to the specified program, and is displayed in a convenient form for the operator on the display connecter to a microcontroller.

- The disadvantage of a circularly rotating potentiometer is the presence of a mechanical part (slider) and the complexity of mounting and installation on the rotating part of the controlled object.

Despite this, potentiometric sensors are successfully used in most systems for controlling the turning angle or linear movement.

The disadvantages of a 4-bit incremental encoder with a photoelectric output are a large conversion error and a relatively narrow range of rotation angle control (only 32°). Another disadvantage is the occurrence of errors when crossing the boundaries of individual discrete sections. Such shortcomings limit the use of these encoders to control changes in the angle of the position of shafts, wheels, etc.

The advantages of absolute encoders are: they have an output communication interface with a field bus according to the CANopen, ProfiBus, DeviceNet, Ethernet, InterBus standards. The disadvantages of absolute encoders are that they are complex in design and are more expensive.

Thus, absolute encoders (single-turn) can be successfully used to control the turning angle of shafts with low (small) rotation speeds in a wide range of turning angle. The output data is stored for a long time. In addition to these, the outputs of the absolute encoders are connected to a serial communication interface, which makes it possible to transmit and process measured data at a distance. This enables the machine operator to visually observe on the display the angle of position of the drive wheel of the cotton picker.

An analysis of the principles of construction and operation of various types of magnetic encoders showed that it is difficult to use them to control the wheel turning angle. They can be successfully used to control the rotation speeds of high speed shafts. The main advantages of magnetic encoders are high reliability and durability, which are ensured by the non-contact connection of the elements of the magnet and the Hall sensor.

Summarizing the results of the analysis, the following conclusions can be drawn:

- to control the turning angle of tractor steering wheel, if not taken into account the high cost, can be uses an absolute optical encoder;

- to control the change in the position of the angle of rotation of the driving wheel of the tractor, if mechanical contact is not taken into account, you can use a cheap circularly rotating potentiometric sensor;

- Absolute magnetic encoders can be successfully used to control turning angle of shafts of both low and high speeds of rotation in a wide range of angles. Magnetic encoders are characterized by high reliability and durability, which are ensured by contactless connection of the elements of the magnet and the Hall sensor. At the same time, the complexity of installing all types of sensors to the axis of the rotating part of the steering wheel remains the same.

References:

1. Matchanov, R., Rizayev, A., Astanakulov, K., Tolibaev, A., & Karimov, N. (2021). Combined cotton picker with interchangeable devices. IOP Conference Series: Earth and Environmental Science, 677, 052021. https://doi.org/10.1088/1755-1315/677/5/052021

2. Uljaev, E. U., & Ubaydullaev, U. M. (2018). Cotton picker's spindle speed control by measuring sensoe frequency. Chemical Technology, Control and Management, 2018(2), 37–42.

3. Khanpara, B., & Kathiria, R. (2023). Development and performance evaluation of picking mechanism for knapsack cotton picker. INTERNATIONAL JOURNAL OF AGRICULTURAL SCIENCES, 19, 145–152. https://doi.org/10.15740/HAS/IJAS/19.1/145-152

4. Эркин Улжаев, Уткиржон Убайдуллаев, Султонбек Эркинов, & Собир Шеркобилов. (2014). Автоматизированное устройство контроля забои давления воздуха в пневмотранспортной камере хлопкоуборочной машины. In Сборник материалов международной научно-технической конференции на тему: "Современные материалы, техника и технологии в машиностроении" 19-20 апреля 2014 года. Том-1. Андижан.

5. Uljayev, E., Ravutov, S. T., & Ubaydullayev, U. M. (2020). Remote control device to control the contact uniformity of the brush strippers on the spindle's surface of the cotton picking apparatus. In IOP Conference Series: Earth and Environmental Science (Vol. 614, p. 012139). IOP Publishing.

6. Chen, H., Wang, M., Ni, X., Cai, W., Zhong, C., Ye, H., … Lin, Y. (2023). Design of Hydrostatic Power Shift Compound Drive System for Cotton Picker Experiment. Agriculture, 13, 1591. https://doi.org/10.3390/agriculture13081591

7. Liu, Z., & Zhang, L. (2020). A review of failure modes, condition monitoring and fault diagnosis methods for large-scale wind turbine bearings. Measurement, 149,

107002. https://doi.org/10.1016/j.measurement.2019.107002

8. Bertolotti, F., Sbonnik, S., & Sumbeck, T. (2014, September 9). Angular position encoder for a rotating shaft.

9. Ulzhayev, E., Ubaydullayev, U. M., & Ulzhayev, Z. E. (2014). Electronic on-board control system of operational and technological parameters of cotton harvesting units. Traktory i sel hozmashiny, 81(10), 11–14.

10. Barros, T., Lins, I., & Moura, M. (2023). Deep Learning Models Applied to Intelligent Diagnosis of Rotating Machines.

11. Liu, Y., Chen, B., & Chang, J. (2015). Development of polarity-changeable magnetizer for manufacturing coding patterns in rotary encoder. https://doi.org/10.1109/INTMAG.2015.7157742

12. Улжаев, Э., Убайдуллаев, У., & Абдулхамидов, А. (2021). Выбор способов и датчиков контроля изменения ширины между перемещающими объектов. InterConf.

13. Gao, X., & Zhang, X. (2022). A Multivector Variable Area Type Capacitive Angular Displacement Encoder Based on a Rotating Electric Field and Improvement of Its Demodulation Method. IEEE Sensors Journal, PP, 1–1. https://doi.org/10.1109/JSEN.2022.3200099

14. Абдазимов, А. Д., Улжаев, Э., Убайдуллаев, У. М., & Омонов, Н. Н. (2014). Основы автоматизации контроля и управления технологическими параметрами хлопкоуборочных машин. Ташкент: ТашГТУ.

15. Эркин Улжаев, Уткиржон Убайдуллаев, & Тоштемир Авезов. (2014). Микропроцессорное устройство контроля угла поворота ведущего колеса сельхозмашин. In Сборник материалов международной научно-технической конференции на тему: “Современные материалы, техника и технологии в машиностроении” 19-20 апреля 2014 года. Том-1. Presented at the Сборник материалов международной научно-технической конференции на тему: “Современные материалы, техника и технологии в машиностроении” 19-20 апреля 2014 года. Том-1., Андижан.

16. Ellin, A., & Dolsak, G. (2008). The design and application of rotary encoders. Sensor Review, 28, 150–158. https://doi.org/10.1108/02602280810856723

17. Lee, J., Wu, F., Zhao, W., Ghaffari, M., Liao, L., & Siegel, D. (2014). Prognostics and health management design for rotary machinery systems—Reviews, methodology and applications. Mechanical Systems and Signal Processing, 42(1), 314–334. https://doi.org/10.1016/j.ymssp.2013.06.004

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THE INTERACTION OF THE COTTON PIECE WITH THE PILES OF THE SCRABBLE COTTON DRUM

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Abstract. *This article presents the results of an analytical study of the process of loosening and cleaning raw cotton from small debris by pileging working bodies of purifiers, on the basis of which directions for further research were chosen to optimize the parameters of the developed pile drum with spherical piles and rubber strips.*

Cotton entering production contains impurities. The processes of loosening and cleaning the fiber shreds are key in the initial stages of ginning, as they prepare the raw cotton for ginning and directly affect the reliability, productivity of these processes and the quality of the resulting fiber.

Weed impurities are divided into large and small. Weed impurities larger than 8 mm are classified as large debris. Weed impurities are located, as a rule, on the surface of the structural particles of raw cotton, and inside the lobules and flakes, having weak varying degrees of adhesion to the fiber. The efficiency of cleaning raw cotton from impurities largely depends on its qualitative characteristics: the selected cotton variety, humidity, industrial grade, fiber length, residence time of impurities in raw cotton, th e nature of the litter and other indicators. Drum cleaners are used to separate small impurities from raw cotton.

Key words: *weeds, loosening, cleaning, intensity, impact, main part.*

Annotatsiya: *Ushbu maqolada paxta xomashyosini tozalagichlarning ishchi organlarini takomillashtirish orqali mayda ifloslikdan tozalash va tozalash darayonini tahliliy o‘rganish*

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