Analysis and Prospect of Key Technologies for Crop Straw Recycling

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Abstract. For the whole process of straw recycling and processing of various general crop harvesters, summarize and analyze the current key technology research in the fields of crop straw recycling and processing technology, foreign matter detection and positioning technology, crop cleaning technology, robot technology, etc., aiming at the efficient recovery of crop straw, the efficient and accurate detection and positioning methods of foreign matters such as stones, soil blocks and metals, the rapid removal of foreign matters. Prospects are made in several key technologies, corresponding technical innovation suggestions are put forward for designers in related fields. It will help to obtain the straw recovery and precise foreign matter detection system that is universal for general agricultural machinery and help the development of efficient and precise agriculture all over the world.

Keywords: Straw recycling; foreign matter detection; crop cleaning; removal of foreign matter.

1. Introduction

With the continuous improvement of residents' living standards and quality, the demand for dairy products and meat such as cattle and sheep is also increasing year by year. High-quality products cannot be separated from efficient and high-quality feeding. The green fodder is the main feed of the animals, the mechanization and high-quality preparation of its harvesting has become a key link in the efficient development of animal husbandry [1]. Silage or yellow silage is one of the most important ways to reserve feed, which can not only save the cost of feed, but also adjust the supply period of forage, solve the problem of seasonal shortage of feed, reduce straw burning, and promote a virtuous circle of agriculture. It is a sustainable development technology [2].

2. Research Status and Problem Analsist

Most straw harvesting is to install straw picking and harvesting device on the original harvester. Metals, stones, clods and other foreign objects in the field enter the header with the straw, which will damage the mechanical transmission mechanism and the fixed cutter, reduce production efficiency, and seriously reduce the production efficiency. The quality of silage has a serious impact on the health of animals [1].

Germany CLAAS Agricultural Machinery Company successfully developed a metal detection device in 2006, which has many functions such as stone, metal and other foreign body detection, automatic knife sharpening, self-adjustment of cutting length and grain crushing, representing the highest technical level and future development of silage harvesters' trend [3]. The metal detection system developed by John Deere Company in the United States, combined with the special roller mechanism design, can quickly disengage the feed roller within 1s to prevent metal foreign objects from entering. The Metal III system of New Holland Company detects and displays the position of foreign objects in real time, the drum reverses, and the metal is taken out [1]. The Menoble uses metal detection sensors from WTK Electronic, Chinese Academy of Agricultural Mechanization Sciences has developed a metal foreign body detection system for green feeders, which must be stopped manually to remove foreign bodies [1]. Most of the above detection methods can only detect metal, even iron foreign objects, have strict requirements on vibration and magnetic fields, and have poor anti-interference ability, requiring shutdown and manual removal, low efficiency, and great potential safety hazard [4].

3. Prospect of Key Technologies for Crop Straw Recycling

Based on the above status and problem analysis, the whole process of straw recycling and processing of general crop harvesters is taken as the core, combined with the key technologies in the fields of crop straw recycling and processing, detection and positioning of adulterated foreign objects, crop cleaning, robots and other fields. The

efficient and accurate detection and positioning methods, efficient cleaning and rapid autonomous removal of foreign objects such as stones, clods and metals are prospected in detail.

3.1 Technical Prospect of Crop Straw Recycling System

Aiming at the harvesting principle and steps of the straw recovery mechanism of the crop harvester, it focuses on the technical prospect of the mechanical structure and characteristics, dynamic characteristics and control process related to the processing of silage raw materials such as straw and ear bark.

Taking corn harvesters as an example, most corn harvesters have the function of collecting and crushing straw after picking ears. Research and improve the design of the transmission mechanism after straw collection and before crushing. After the ear is peeled, the ear bark and straw are collected together. For the harvester with the stubble height adjustment function, reduce the stubble height within the allowable range. For the harvester without this function, research and design the stubble left separate harvesting and collection mechanism to improve straw recovery rate. The collected silage raw materials such as straw, ear skin and field stubble after ear picking are concentrated on the foreign body detection and transmission workbench before the straw is crushed. The transfer table must have the functions of coarse vibration filtering, accurate detection and positioning of residual foreign objects, and robot grasping and elimination.

The design of the straw recycling system must be deeply combined with the mechanical structure characteristics of the harvester, and strive to achieve the recycling of valuable straw and ear skins simply and efficiently, so as to achieve seamless connection with the original mechanical parts and highly match the power system of the original machinery, to avoid excessive increase in mechanical structure and power configuration.

3.2 Technical Prospect of Foreign Matter Frequency Conversion Vibration Filtration System

By studying the cleaning principles and cleaning methods of crops such as grains commonly used in general agricultural machinery, we can grasp the obvious difference characteristics of foreign objects such as stones, clods and metals in the straw, and estimate the possible foreign objects and sizes of foreign objects. Combined with the cleaning style of soybean and wheat, design a vibrating filter screen with variable frequency for foreign matter, it is necessary to design appropriate screen holes and structures, and determine key parameters such as the vibration frequency and inclination angle of the screen through experiments to efficiently filter out a certain volume of stones and soil blocks or foreign objects such as metals.

During the working process of the filtration system, the vibration frequency and inclination angle of the sieve can be adjusted in real time according to the characteristics of the foreign body volume and density detected by the detection system, and strive to filter out most foreign bodies through frequency conversion vibration. Through the foreign body vibration filtering system, a certain volume of foreign bodies such as stones, clods or metals are filtered out, and the crop straw enters the next stage of the foreign body detection and removal process.

3.3 Technology Prospect of Residual Foreign Object Accurate Detection and Positioning System

Considering that the detection objects are foreign objects such as stones, clods and metals mixed in crop straw, the location of foreign matter is uncertain, and a single detection method such as metal detection cannot detect foreign objects such as stones and clods. Ordinary image processing technology is not suitable for the detection of foreign matter hidden under the straw or inside the straw. Considering the characteristics of the straw containing foreign matter laid on the transmission table, the methods including laser triangulation, eddy current method, ultrasonic measurement method, machine vision measurement, infrared detection, X-ray detection and other non-contact detection methods are used for detection and positioning. Through experiments to determine the detection parameters of various common foreign objects and straw, and establish a detection feature library, the following three methods can be adopted to complete the accurate measurement of parameters such as the volume and position of residual foreign objects in straw.

3.3.1 Comprehensive detection and positioning method of the transmission workbench

When the detection method is achievable and the cost allows, a comprehensive detection and positioning system covering the entire transfer table is adopted. The detection system will perform full-coverage real-time detection on the straw containing foreign matter laid on the transmission workbench, and feed back the detected value of the volume and position of the foreign matter to the control system in the form of absolute coordinates.

3.3.2 Feed port detection and positioning method

Limited by the detection method or cost control, the detection and positioning method of the feed inlet is adopted to simplify the detection mechanism and production cost. The sensor of the detection system adopts a linear design and installation method, and is installed at a reasonable position near the feed port of the transmission workbench or the feed port. The volume and position detection values of foreign objects are fed back to the control system by relative coordinates. The parameters related to the running displacement of the transmission table must be fed back to the control system in real time, and the control system can obtain the precise parameters of the foreign object through the conversion of coordinates and volume.

For the displacement detection of the workbench, full-closed loop or semi-closed loop feedback can be used. If

full closed-loop feedback is used, a displacement detection device such as a grating ruler should be installed in the direction of the parallel transmission table for detection, and the detection accuracy is high. If the semi-closed-loop feedback method is adopted, the uniform running speed and running time of the transmission table can be fed back together in real time, and obtained through conversion by the control system, or a detection device such as an encoder to measure the rotation angle can be installed on the transmission table drive shaft or motor, which is obtained by conversion in combination with the transmission parameters of the worktable.

3.3.3 Mobile scanning detection and positioning method

Install the non-contact detection device at the appropriate position of the robot grasping platform, reasonably plan the running trajectory of the robot, conduct real-time dynamic and comprehensive detection of foreign objects, and cooperate with the robot to achieve efficient and accurate foreign object positioning, grasping and elimination through relative coordinate information.

3.4 Technology Prospect of Foreign Object Removal System

Through the processing of the first few processes such as primary screening and foreign object detection and positioning, combined with the characteristics of the straw containing foreign objects laid on the transfer table and the volume and position information of foreign objects obtained by the detection unit, a robot grasping and elimination system must be designed. It consists of X-Y motion subsystem, robot motion subsystem and grasping subsystem, which are installed directly above the transmission table. The motion of the robot is driven by a three-dimensional motion platform, and its working range effectively covers the entire working area.

3.4.1 X-Y working subsystem

The X-Y working subsystem is installed just above the transmission table, and its mechanical system is driven by a synchronous belt or a rack-and-pinion mechanism, and the drive system is controlled by a high-precision stepper motor or AC servo motor with its own encoder. The secondary position sensor performs safety detection, alarm and emergency stop to ensure the safe and efficient operation of the system. The X-Y working subsystem combines the precise position and volume of the foreign body obtained by the control system to accurately locate the foreign body.

3.4.2 Robot motion subsystem

Combined with the harvester's own power situation and cost control requirements, the mechanical mechanism of the robot motion subsystem can realize the telescopic motion control of the mechanical mechanism through pneumatic, hydraulic or AC servo motors. According to

the positioning data of foreign objects, the XY working subsystem efficiently and accurately operates the mechanical gripper of the robot motion subsystem to the effective grasping working range. Limited by the characteristics and space of the mechanical part of the harvester, a two-axis or three-axis robot motion system can be designed according to specific user needs, which is convenient for accurately and efficiently grasping and discharging foreign objects.

3.4.3 Robotic grasping subsystem

Considering the mixing of foreign objects and crop straws, the foreign objects may be exposed on the surface of the straw, or mixed in the middle of the straw or covered by the straw at the bottom of the transmission table. Combined with the volume data of the foreign objects, a special robot grasping mechanism is designed. The mechanism must have practical functions such as crop straw cutting and foreign matter grasping. After the X-Y working subsystem moves the robot to the effective grasping working range, the straw cutting and grasping mechanism of the robot cuts off part of the straw around the foreign object radially under the control of the robot motion subsystem, and grabs it together with the foreign object, and then passes through a special discharge channel discharges the foreign matter and discards it.

4. Summary

Taking the general crop harvester as the research object, he has consulted many Chinese and foreign papers and works on the recycling technology of valuable straw such as crop straw, ear bark and the mainstream detection technology, positioning technology and removal technology of foreign objects such as stones, clods and metals. And research results, in-depth investigation and research on the domestic and foreign crop harvesting machinery market and the mainstream products and technical characteristics of medium and large agricultural machinery enterprises, and accurately grasp the most cutting-edge research directions in the world and the current problems in the field of harvesting machinery. Facing the general crop harvester, the key technical fields such as efficient recovery of crop straw, detection, positioning and cleaning of straw-doped foreign matter are prospected, and some suggestions for technological innovation are put forward.

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