Development of Intelligent Rice-Wheat Combine Harvesting and Baling Machine

Huaizhuang Tang¹,a, Xiusheng Chen¹,b,⁎, Zhiyuan Xue¹,c, Xiaoming Xing²,d, Mengwei Li¹,e, Guodong Lv¹,f, Hejia Guo³,g

¹School of Mechanical Engineering, University of Jinan, Jinan, China
²School of Political Science and Law, University of Jinan, Jinan, China
³Department of Design, Shandong Jindafeng Machinery Co., Ltd., Jining, China

b,* me_chenxs@ujn.edu.cn,

d,tanghuaizhuang@qq.com

b,* Corresponding author: 57909330@qq.com

c305116022@qq.com
d2776349638@qq.com
e1014581128@qq.com
f513266610@qq.com
gguohejia2008@163.com

Abstract—At present, due to the low utilization rate of straw, the environmental problems caused by straw burning are outstanding. Straw turns to a bioenergy technology has made breakthroughs and can be invoked as feed and power generation after treatment. We lack machinery for combining operations of rice-wheat harvesting and straw bundling in China. Because of the current status of rice-wheat harvesting and bundling, which have been successively entered into field operations by two machines, we have developed rice-wheat combined harvesting and threshing, and straw bundling with smart control. The intelligent rice-wheat combined harvesting and bundling machine with combined functions has completed the development of two prototypes, entrusted an inspection agency to perform inspection and testing, all performance indicators were better than the field safety and operational performance test. The machine integrates the functions of combined harvesting and bundling of rice and wheat and realizes the efficient harvesting of grains and the recycling of straw, which has been well reflected by users and has a fair prospect of promotion and application.

1. INTRODUCTION

At present, due to the low utilization rate of straw, the environmental problems caused by straw burning are outstanding, and only part of it is used as feed to feed cattle and sheep. The traditional straw treatment method is generally to return to the field or burn it directly [1]. With the increase of environmental protection pressure, the prohibition of straw burning has become a key task of the government every time the grain is harvested. Fortunately, the comprehensive utilization technology of straw, which can become biomass energy after treatment, has made breakthroughs. Straw can be used
as a raw material for papermaking and biomass energy. It cannot only solve environmental problems but also turn waste into a treasure which increases farmers' income.

However, we lack machinery for the combined operation of rice-wheat harvesting and straw bundling in China [2]. The combine harvester and baler are always developing along their respective routes [3]. Because the baler enters the farmland under the tractor's traction and bales the threshing straw [4,5], which improves the cost. As we all know, rice and wheat are the most important food crops in my country. Combined with my country's actual situation, the development of rice and wheat harvesting machinery suitable for the national conditions is the only way for the progress of my country's agronomic machinery industry. Since my country's rural auxiliary power is relatively minute, fields are tiny, and farmers' purchasing power is low. It is not feasible to copy the development ideas of developing countries completely.

Driven by strong agricultural machinery subsidy policy, my country’s combine harvester market has developed strongly. With the breakthrough in volume, the market structure has also quietly changed [6]. High-configuration combined harvesters are welcomed in the market [7], and the proportion of sales has increased substantially [8]. With the increase of users' purchasing power, the sales ratio of luxury comfortable and high-end configuration products has increased significantly, and the upgrade of supporting power has been obvious. These products have developed towards the direction of high power, high efficiency, high added value and high technology content. The growth rate of high-performance models is accelerated.

2. METHODS

Given the current situation in which rice and wheat harvesting and bundling are successively entered into field operations by two machines, a rice-wheat combined harvesting and bundling machine is developed to combine rice-wheat mechanized combined harvesting and rice-wheat straw bundling operations to achieve rice-wheat harvesting and straw bale integration operation, and intelligent control of the above process. There are some key technologies and innovations developed as follows.

2.1 Harvesting and bundling technology for large-feed rice and wheat

After investigating three major plain areas of my country, users have increasingly improved performance requirements such as the harvesting efficiency and reliability of the harvester. Grain harvesters with a feed volume of more than 7 kg/s are hot spots in the market. Through the integration of the harvester and the balers on the same machine, efficient grain harvesting and straw recycling are made.

2.2 The bright monitoring system

It realizes the distant monitoring of the machine operation process. It can detect the transmission parameters, working to track and status of the harvester drummed rotation speed and can realize real-time early warning and remote shutdown control. The technical research of the smart and programmed fault detection system mainly includes the following three aspects:

- Research on the dynamic real-time remote monitoring technology of the harvester's operating parameters, geographic location, working hours and other conditions.
- The traditional separation of the harvester based on the parameter collection and display alarm. System faults with abnormal parameters are used to conduct button detection technology research.
- The mechanical-hydraulic integration technology of self-regulating control and push-button overload protection of the harvester.

2.3 The new separation and threshing technology

The cross-flow pre-acceleration feed horizontal axis flowed separation and mixing threshing technology can realize high-efficiency large-feed operation. The use of the widened bridge and widened flow-
cutting rollers ensure that crops are transported more evenly and smoothly, and threshing performance is more reliable.

2.4 Optimize the structure
The optimally designed threshing and cleaning device reduced the rate of seed loss and breakage and used CAE software to analyze key components to achieve a reasonable arrangement and optimized design of the working device.

2.5 Forced feeding drum
The designed forced feeding drum improves the feeding speed and baling quality of the baler. The threshing straw is transported to the baler to ensure the normal operation. The bundle is dense and will not be scattered, and the size of the bundle is moderate, which is convenient for loading and transportation such as Fig. 1.

![Rice straw bales.](image)

Figure 1. Rice straw bales.

2.6 Reliable walking system
The dual-pump dual-motor full-hydraulic walking system can realize steeples speed change and reverse movement of the left and right crawlers in-situ turning, reducing rolling damage to the ground. The motor can realize a hydraulic pilot two-speed switching and high braking torque. Two plunger pumps are separately controlled by the handle, and the two-speed variable motors are individually controlled by the pumps to realize the forward, backward, braking, steering, and in-situ rotation of the equipment.

3. RESULTS
To verify the operation of the bright application level and the effect of bundling, we selected 22 hectares as the test prototype. Among them, the harvesting device, hydraulic walking device, clever monitoring system, navigation positioning, and automatic bundling system can be realized.

To verify the quality of the machine, the product quality testing center of the Shandong Academy of Agricultural Machinery Sciences was commissioned to test the wheat and rice harvesting tests separately. The results showed that all performance indicators were better than the field safety and operational performance test. Enterprise standards and relevant national standards in Table 1. Depending on the trial users, the machine has the advantages of good harvest effect, low failure rate, simple operation, convenient maintenance, fast walking speed, and so on.
| Number | Project       | Unit | Specifications          | Wheat | Rice |
|--------|---------------|------|-------------------------|-------|------|
| 1      | Power         | kW   | 132                     |       |      |
| 2      | Feed volume   | kg/s | 7.0                     | 7.1   |      |
| 3      | Total loss rate | %    | ≤0.36                   | 0.85  |      |
| 4      | Grain breaking rate | % | 0.16                     | 0.32  |      |
| 5      | Grain impurity rate | % | 0.55                     | 0.82  |      |
| 6      | Cut width     | mm   | 2750                    |       |      |
| 7      | Bundle rate   | %    | 99                      | 100   |      |
| 8      | Bale density  | kg/m³ | 154.0                   | 119.7 |      |
| 9      | Bundle material consumption | kg/t | 0.863                   | 0.979 |      |
| 10     | Packing section | mm | 320*420                 |       |      |
| 11     | Packing length | mm | 654.7                   | 643.3 |      |

Similar power in the domestic and project models. The closer is the LOVOL GE60. However, GE60 only can harvest wheat, not bale straw. This machine has advantages over GE60 in both wheat and rice harvesting. The key components adopt domestic mature supporting resources, which cannot only ensure lower costs but need to make sure product reliability. With the rapid development of agricultural harvesting machinery, there are more and more manufacturers of specialized parts and components, and the manufacturing cost has a large space for reduction. The use of mature resources and grown technologies will provide a powerful guarantee for quality and cost reduction.

4. CONCLUSIONS
The straw is generally processed by crushing and returning to the field in Europe and other Western countries. There is not any commercial cereal combine harvesting and bundling machine. Most of the domestic grain combined harvesters also use a straw to directly introduce into the field. In recent years, the feeding volume of the combined harvester and baler is generally 2-3 kg/s and the market scale is small. This product can realize the combination of high-efficiency harvesting of rice and wheat and straw bale recovery, and has achieved the technical breakthrough of the integration of harvesting and bale integration of large-feed grains.

The machine combines the functions of combined harvesting and bundling of rice and wheat, which realizes the efficient harvesting of grains and the recycling of straw, and has the advantages of high operating efficiency, excellent reliability, and decent adaptability. The experimental verification area is 22 hectares, which is well reflected by users and has an excellent prospect of promotion and application. Straw can become biomass energy after being treated. The successful development and promotion of the rice-wheat combined harvesting and bundling machine is beneficial to solve the environmental pollution problem caused by straw burning completely. This product creates favorable conditions for local farmers to increase their income by going to work. The successful development of this product, bundled at the time of harvesting, to avoid problems such as the accumulation of straw due to weather changes, and the failure to follow up cultivation, etc., which plays a role in saving resources and protecting the environment, and has valid social and ecological benefits.

ACKNOWLEDGMENT
Thanks to the school and tutor for giving this article guidance, and thanks to the editor for their responsible review and feedback. This work was financially supported by Major Science and Technology Innovation Program of Shandong Province in 2018 (2018CXGC0216) fund.

This work was financially supported by Major Science and Technology Innovation Program of Shandong Province in 2018 (2018CXGC0216) fund.
REFERENCES

[1] Z. Zhao, Y.M. Li, J. Chen, and J.J. Xu, “Grain separation loss monitoring system in combine harvester,” Comp. Elect. Agri, vol. 76, pp. 183–188, May 2011.

[2] G. Craessaerts, J.D. Baerdemaeker, B. Missotten, and W.Saeys, “Fuzzy control of the cleaning process on a combine harvester,” Bios. Engi, vol. 106, pp. 103–111, June 2010.

[3] Z.W. Liang, Y.M. Li, J.D. Baerdemaeker, L.Z. Xu, and W. Saeys, “Development and testing of a multi-duct cleaning device for tangential-longitudinal flow rice combine harvesters,” Bios. Engi, vol. 182, pp. 95–106, June 2019.

[4] J. Pang, Y.M. Li, J.T. Ji, and L.Z. Xu, “Vibration excitation identification and control of the cutter of a combine harvester using triaxial accelerometers and partial coherence sorting,” Bios. Engi, vol. 185, pp. 25–34, September 2019.

[5] J.H. Qin, Z.H. Zhu, H.Y. Ji, Z.X. Zhu, Z. Li, Y.F. Du, Z.H. Song, and E. Mao, “Simulation of active steering control for the prevention of tractor dynamic rollover on random road surfaces,” Bios. Engi, vol. 185, pp. 135–149, September 2019.

[6] H.P. Si, Y.L. Li, C.X. Sun, H.B. Qiao, and X.H. Hu, “A hierarchical game approach on real-time navigation scheduling of agricultural harvesters,” Comp. Elect. Agri, vol. 162, pp. 112–118, July 2019.

[7] L.Z. Xu, C.C. Wei, Z.W. Liang, X.Y. Chai, Y.M. Li, and Q. Liu, “Development of rapeseed cleaning loss monitoring system and experiments in a combine harvester,” Bios. Engi, vol. 178, pp. 118–130, February 2019.

[8] Y.X. Yin, Y.W. Zhang, Z.J. Meng, C. Du, W.C. Qin, and S.X Guo, “Design and Experiment of Multi-information Collection System for Grain Combine Harvesters,” IFAC. Pap. Online, vol. 51, pp. 855–860, 2018.