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The influence of combine drive design parameters on corn grain harvesting efficiency

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Article info

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The article investigates the impact of design parameters of grain combine harvester drives on the productivity, efficiency, and quality of corn grain harvesting. Considering current requirements for agrotechnological processes, particular attention is paid to the type of power transmission, gear ratio, adaptability of control systems, and energy efficiency of the drives. The research was conducted under field test conditions using modified models of combine harvesters equipped with different types of drive systems: mechanical, hydraulic, and adaptive hydraulic. The conducted analysis proves that the design parameters of the drive system significantly influence the technical and operational performance during corn harvesting. Specifically, parameters such as transmission type, gear ratio, adaptability, and energy efficiency determine the operational stability, grain loss rate, fuel consumption, and the quality of grain cleaning. The study results showed that the most effective system is the adaptive hydraulic drive, which ensures productivity of 33.2 t/h, minimizes grain losses to 0.6%, and reduces specific fuel consumption to 1.5 L/t. Mathematical analysis revealed a high degree of correlation between productivity and grain losses, cleaning quality, and energy consumption, confirming the advisability of improving drives in the direction of flexible mode regulation. The scientific novelty of the work lies in identifying a quantitative relationship between the drive type and the combine's comprehensive efficiency indicators, justifying the implementation of adaptive hydraulic systems in harvesting machinery. The practical significance of the study lies in the possibility of applying the obtained results for modernizing the existing fleet of machines and developing new technical solutions aimed at increasing productivity and reducing energy consumption in the grain harvesting process. The obtained results can serve as a basis for improving the existing designs of grain harvesters and for developing new adaptive drive systems that meet energy-saving, reliability, and high-quality technological process requirements.

Keywords: combine harvester, productivity, drive, grain loss, energy efficiency.

Вплив конструктивних параметрів приводу комбайна на продуктивність збирання зерна кукурудзи

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У статті досліджено вплив конструктивних параметрів приводів зернозбиральних комбайнів на продуктивність, ефективність та якість збирання зерна кукурудзи. Враховуючи сучасні вимоги до агротехнічного процесу, особлива увага приділяється типу передавання енергії, передаточному числу, адаптивності систем керування та енергоефективності приводів. Дослідження проводилося в умовах польових випробувань із використанням модифікованих моделей комбайнів, оснащених різними типами приводних систем: механічним, гідравлічним та адаптивним гідравлічним. Проведений аналіз доводить, що конструктивні параметри приводної системи зернозбирального комбайна мають суттєвий вплив на техніко-експлуатаційні показники при збиранні зерна кукурудзи. Зокрема, параметри типу передавання, передаточного числа, адаптивності та енергоефективності визначають стабільність роботи, рівень втрат зерна, витрати пального та якість очищення продукції. Результати досліджень засвідчили, що найбільш ефективною є система з адаптивним гідравлічним приводом, яка дозволяє забезпечити продуктивність на рівні 33,2 т/год, мінімізувати втрати до 0,6 % і зменшити питомі витрати пального до 1,5 л/т. Математичний аналіз виявив високий ступінь кореляції між продуктивністю і втратами зерна, якістю очищення та витратами енергії, що підтверджує доцільність вдосконалення приводів у напрямку гнучкого регулювання режимів роботи. Наукова новизна роботи полягає у виявленні кількісної залежності між типом приводу та комплексними показниками ефективності комбайна, що дозволяє обґрунтувати доцільність впровадження адаптивних гідравлічних систем у зернозбиральну техніку. Практичне значення дослідження полягає в можливості застосування отриманих результатів для модернізації існуючого машинного парку та розробки нових технічних рішень, орієнтованих на підвищення продуктивності та зниження енергозатрат у зернозбиральному процесі. Отримані результати можуть бути використані як основа для вдосконалення існуючих конструкцій зернозбиральних машин, а також для розробки нових адаптивних приводів з урахуванням вимог енергоощадності, надійності та високої якості технологічного процесу.

Ключові слова: комбайн, продуктивність, привід, втрати зерна, енергоефективність

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Introduction

In modern agro-industrial production, the efficiency of technological processes for harvesting grain crops, particularly maize [1, 2], plays a crucial role. Maize is a strategic crop for many countries around the world. Maize grain is widely used not only in the food industry, but also in animal husbandry, bioenergy, and pharmaceuticals. Given its economic and agronomic importance, improving the performance of harvesting machines – especially corn harvesters – has become an urgent issue [3].

Scientific literature highlights considerable attention to improving the design of harvesters, especially the drive systems that ensure the operation of key components of the machines [4]. In particular, publications from the United States, European Union countries, China, and Brazil actively explore ways to increase the technical and technological efficiency of harvesting machinery. The primary focus is on optimizing drive systems, which play a key role in ensuring stable, efficient, and energy-saving operation of harvesters under varying agrotechnical conditions [5, 6].

In their study, Zhang et al. [7] focused on improving harvesting mechanisms by reducing mechanical losses and increasing energy efficiency through the adaptation of drive speed modes. Similarly, Gu et al. [8] demonstrated that the use of computer modeling in the design of drive systems can reduce energy consumption by 10–15 %, which is particularly significant in the context of the ongoing energy crisis.

An important aspect in the design of combine harvesters is the precision of speed control. For example, Tang et al. [9] presented a multifunctional grain harvester that integrates both harvesting and baling functions. The use of electric drives with precise rotational speed control improved machine maneuverability, especially in areas with variable crop density. This highlights the potential of transitioning to electronically controlled systems capable of real-time adaptation to field conditions.

The publication by Nadai et al. [10] describes the use of a hybrid artificial neural network model to optimize the operational parameters of a combine harvester's drive system. Utilizing self-adaptive algorithms, the system autonomously adjusted the rotational modes of drums and conveyors according to real-time conditions, which led to a 12 % increase in productivity and a 7 % reduction in grain loss.

Ukrainian researchers [11] are also conducting studies aimed at improving combine harvester drive systems. However, most existing works focus on general technical specifications of the machines or individual components, without providing a comprehensive analysis of the relationship between the structural parameters of the drive system and actual harvesting performance under real agrotechnical conditions.

Studies [12–15] present an experimental evaluation of grain harvester operation in field conditions. The primary focus is on the influence of various technical parameters and operational conditions on harvesting efficiency. The research examines grain losses, fuel consumption, and operating speeds, drawing conclusions about directions for machine improvement, particularly in the area of drive systems.

The core of the problem lies in the fact that the structural features of the drive system – such as the type of torque transmission, speed controllability, the type and characteristics of gearboxes, and the use of energy-saving technologies directly affect the stability of working units, the level of mechanical losses, and the uniformity of harvested material flow [16, 17]. Failure to account for these factors in the design and operation of harvesting machines may lead to reduced productivity, increased energy consumption, and deterioration of product quality [18–20].

The relevance of this research topic is driven by the need to enhance the competitiveness of domestic agricultural production, which requires technical modernization based on advanced engineering solutions. This is especially true for the drive systems of corn harvesters, whose efficiency determines the machine's performance under variable plant density, moisture levels, terrain unevenness, and other agrotechnical factors.

Therefore, studying the influence of the structural parameters of combine drive systems on the performance of corn grain harvesting is a crucial step toward the development of efficient, reliable, and energy-saving agricultural machinery adapted to the modern challenges of agricultural production.

The aim of the study

The study was conducted to determine the influence of the structural parameters of the drive system of a grain harvester on the performance and quality of corn grain harvesting under production field conditions.

Materials and methods

The primary subject of the research was John Deere combine harvesters, focusing specifically on the design of conveyor drives and feed drive systems.

The structural parameters under investigation included the type of transmission (mechanical or hydraulic), gearbox gear ratio, the presence of an adaptive speed control system, as well as the mass and placement of drive components. Corn harvesting was carried out over an area of 1 hectare with an average yield of 8.4 tons per hectare.

To assess harvester performance, the following methods were used: fuel consumption tracking, timing of the technological cycle, analysis of harvested grain mass per unit of time, and measurement of grain losses at different stages of the harvesting process. Grain cleaning quality was evaluated using a laboratory separator, and energy efficiency indicators were determined by calculating the specific fuel consumption per ton of harvested material.

The collected data were processed using Excel and MATLAB software, applying methods such as correlation analysis, regression modeling, and variance analysis. The results were presented in the form of graphs, diagrams, and tables, which made it possible to identify the relationships between the structural parameters of the

drive systems and the technical and operational indicators of the harvester.

Results and discussion

The conducted research made it possible to compare the efficiency of three types of drive systems used in grain harvesters: mechanical, hydraulic, and adaptive hydraulic (***Table 1***). The results were evaluated based on the following indicators: productivity, grain losses, fuel consumption, and grain cleaning quality.

Table 1
Research results on the structural parameters of different types of drive systems

Indicator	Mechanical	Hydraulic	Adaptive Hydraulic
Gear ratio	2,5	3,0	2,4–3,2
Productivity, t/h	25,6	28,8	33,2
Grain losses, %	1,1	0,9	0,6
Fuel consumption, L/t	1,9	1,7	1,5
Grain cleaning quality, %	89,5	91,2	93,8

The lowest productivity was observed in the harvester equipped with a mechanical drive – 25.6 t/h. This is attributed to limited speed control capabilities and the lack of adaptation to changing field conditions. The use of a hydraulic drive increases productivity to 28.8 t/h, while the highest efficiency is achieved with the adaptive hydraulic drive, reaching 33.2 t/h. This improvement is due to the presence of an automatic speed regulation system that adjusts the rotation of working units according to crop density, moisture content, and load.

A key indicator of technological efficiency is the grain loss level during harvesting. For the mechanical drive, it amounts to 1.1%, for the hydraulic drive – 0.9 %, while the adaptive hydraulic drive ensures minimal losses of only 0.6%. This is achieved through the stable operation of mechanisms that automatically adapt to real-time working conditions.

Specific fuel consumption per ton of harvested grain is 1.9 L/t for the mechanical drive, 1.7 L/t for the hydraulic drive, and only 1.5 L/t for the adaptive hydraulic drive. This indicates the higher energy efficiency of the latter, which is a crucial factor under rising energy costs.

Grain cleaning quality also varies significantly depending on the type of drive system. The mechanical drive provides 89.5 % purity, the hydraulic drive – 91.2 %, and the adaptive hydraulic drive – 93.8 %. This improvement is achieved through dynamic control of the sieving unit and ventilation systems, which adapt in real time to the characteristics of the harvested material.

The obtained results demonstrate that the use of an adaptive hydraulic drive ensures the best performance across all evaluation criteria. This highlights the potential for further implementation of such systems in mass production and for the modernization of the existing agricultural machinery fleet in Ukraine.

To identify the relationships between the technical parameters of combine drive systems and harvesting performance, a correlation analysis was conducted (***Table 2***). The results showed that the grain loss rate had the strongest correlation (correlation coefficient: –0.9997), indicating an almost linear inverse relationship: as grain losses decrease, productivity increases. A similarly strong inverse correlation was found between productivity and fuel consumption (–0.9959), which suggests more efficient machine performance with reduced energy use.

The strongest positive correlation was found between grain cleaning quality and productivity (0.9996), highlighting the advantage of modern systems capable of adapting to harvesting conditions and delivering high product quality. Meanwhile, the gear ratio showed a moderate positive correlation with productivity (0.5207), indicating a slightly higher influence of this parameter compared to previous findings, although it remains a non-dominant factor in the overall efficiency of the harvesting process.

Table 2
Correlation matrix of technical parameters

	Gear ratio	Productivity, t/h	Grain losses, %	Fuel consumption, L/t	Grain cleaning quality
Gear ratio	1,00	0,52	-0,50	-0,60	0,50
Productivity, t/h	0,52	1,00	-1,00	-1,00	1,00
Grain losses, %	-0,50	-1,00	1,00	1,00	-1,00
Fuel consumption, L/t	-0,59	-1,00	1,00	1,00	-1,00
Grain cleaning quality	0,49	1,00	-1,00	-1,00	1,00

Overall, the results of the mathematical analysis confirm the effectiveness of adaptive hydraulic drives, which enable the reduction of losses, decrease in energy consumption, and improvement in grain cleaning quality, thereby significantly increasing the productivity of the harvesting machine.

Conclusions

1. The conducted analysis demonstrates that the structural parameters of the drive system in grain harvesters have a significant impact on the technical and operational performance indicators during corn grain harvesting. Specifically, parameters such as transmission type, gear ratio, adaptability, and energy efficiency determine the stability of operation, grain loss levels, fuel consumption, and product cleaning quality.

2. The study showed that the use of an adaptive hydraulic drive yields the best results – increasing productivity to 33.2 t/h, reducing grain losses to 0.6 %, lowering specific fuel consumption to 1.5 L/t, and improving cleaning quality to 93.8 %. It was established that adaptive drives ensure stable operation of the main technological systems of the machine through flexible regulation of speed and load modes. This contributes to optimizing grain cleaning quality, which reaches 93.8 % with the use of adaptive drives, a critical factor for enhancing the market value of the harvest.

3. The results of the correlation analysis confirmed a strong inverse relationship between productivity and both grain losses and fuel consumption, as well as a direct relationship with cleaning quality. This substantiates the necessity of improving drive systems specifically towards adaptability and energy efficiency.

4. The obtained results can serve as a basis for improving existing grain harvester designs as well as for developing new adaptive drives that meet the requirements of energy saving, reliability, and high technological process quality.

5. Further research should be directed toward the implementation of intelligent drive control systems based on machine learning, which will enable even greater efficiency in harvesting agricultural crops under variable load conditions.

Conflict of interest

The authors state that there is no conflict of interest.

References

1. Droukas, L., Doulgeri, Z., Tsakiridis, N. L., Triantafyllou, D., Kleitsiotis, I., Mariolis, I., Giakoumis, D., Tzovaras, D., Kateris, D., & Bochtis, D. (2023). A Survey of robotic harvesting systems and enabling technologies. *Journal of Intelligent & Robotic Systems*, 107 (2). https://doi.org/10.1007/s10846-022-01793-z
2. Nowak, B. (2021). Precision agriculture: Where do we stand? A review of the adoption of precision agriculture technologies on field crops farms in developed countries. *Agricultural Research*, 10 (4), 515–522. https://doi.org/10.1007/s40003-021-00539-x
3. Dong, W., Wu, Y., Hu, H., Zhao, J., Liu, F., & Yan, J. (2025). Design and test of self-propelled wide and narrow row corn harvester. *Journal of Chinese Agricultural Mechanization*, 46 (2), 70–74. https://doi.org/10.13733/j.jcam.issn.2095-5553.2025.02.011
4. Prisyazhnaya, I. M., Sinegovskaya, V. T., Prisyazhnaya, S. P., & Sinegovskii, M. O. (2020). Harvester and transporting device development for high-quality soybean seeds obtaining. *IOP Conference Series: Earth and Environmental Science*, 548 (6), 062078. https://doi.org/10.1088/1755-1315/548/6/062078
5. Miralles, G. S., Biglia, A., Mattetti, M., Tortia, C., Gay, P., & Comba, L. (2025). Correlation between satellite multispectral imagery and combine harvester CANbus data for corn yield assessment. *Biosystems Engineering Promoting Resilience to Climate Change - AIIA 2024 - Mid-Term Conference*, 607–614.
6. Xie, Y., & Alleyne, A. (2014). Integrated design and control for header height control of combine harvesters. *Proceedings of the American Control Conference*, 2705–2710. https://doi.org/10.1109/ACC.2014.6858794
7. Zhang, J., Zhao, Z., Gao, Z., Tian, Y., Wang, D., & Xu, N. (2024). Peanut pickup combine harvester seedling vines crushing mechanism performance enhancement and pilot studies. *Agriculture*, 14 (9), 1635. https://doi.org/10.3390/agriculture14091635
8. Gu, X., Zhang, B., Tang, Z., Wang, M., & Liang, Y. (2022). Structure design and performance test of wheat combine harvester based on numerical modeling. *Recent Patents on Mechanical Engineering*, 15 (5), 515–531. https://doi.org/10.2174/2212797615666220826121726
9. Tang, Z., Li, Y., & Cheng, C. (2017). Development of multi-functional combine harvester with grain harvesting and straw baling. *Spanish Journal of Agricultural Research*, 15 (4), e0209. https://doi.org/10.5424/sjar/2017154-11224
10. Nadai, L., Felde, I., Ardabili, S., Gundoshmian, T. M., Gergo, P., & Mosavi, A. (2020). Performance analysis of combine harvester using hybrid model of artificial neural networks particle swarm optimization. *Electrical Engineering and Systems Science*, arXiv preprint arXiv:2002.11041. https://doi.org/10.48550/arXiv.2002.11041
11. Zhuykov, O., Ivaniv, M., Sydiakina, O., & Vozniak, V. (2024). Agrobiological assessment of methods and regimes of combine harvesting of oil flax in the conditions of Southern Steppe of Ukraine. *Journal of Ecological Engineering*, 25 (8), 24–31. https://doi.org/10.12911/22998993/189539
12. Špokas, L., Adamčuk, V., Bulgakov, V., & Nozdrovický, L. (2016). The experimental research of combine harvesters. *Research in Agricultural Engineering*, 62 (3), 106–112. https://doi.org/10.17221/16/2015-RAE
13. Hermann, D., Bilde, M. L., Andersen, N. A., & Ravn, O. (2018). Model-based cleaning fan speed control in a combine harvester: Part I – Identification and optimisation. *Biosystems Engineering*, 169, 1–15. https://doi.org/10.1016/j.biosystemseng.2018.01.004
14. Li, Y., Zhang, X. L., Yaoming, L., Liya, L., & Maolin, S. (2024). Modeling and control methods of a multi-parameter system for threshing and cleaning in grain combine harvesters. *Computers and Electronics in Agriculture*, 225, 109251. https://doi.org/10.1016/j.compag.2024.109251
15. Liang, Z., & Wada, M. E. (2023). Development of cleaning systems for combine harvesters: A review. *Biosystems Engineering*, 236, 79–102. https://doi.org/10.1016/j.biosystemseng.2023.10.018
16. Umbataliyev, N., Smailova, G., Toilybayev, M., Sansyzbayev, K., Koshanova, S., & Bekmukhanbetova, S. (2023). Optimization of the technological process of threshing combine harvester. *Eastern-European Journal of Enterprise Technologies*, 4 (1 (124)), 104–117. https://doi.org/10.15587/1729-4061.2023.285697
17. Fu, J., Xie, G., Ji, C., Wang, W., Zhou, Y., Zhang, G. et al. (2021). Study on the distribution pattern of threshed mixture by drum-shape bar-tooth longitudinal axial flow threshing and separating device. *Agriculture*, 11 (8), 756. https://doi.org/10.3390/agriculture11080756
18. Tang, Z., Li, X., Chen, X., Chen, Y. (2019). Design of negative pressure spiral feeding device for tangential and longitudinal axial intersection of combine harvester. *Advances in Materials Science and Engineering*, 2019, 1–12. https://doi.org/10.1155/2019/1647230
19. Mirzazadeh, A., Abdollahpour, S., Mahmoudi, A., Ramazani, B. (2012). Intelligent modeling of material separation in combine harvester's thresher by ANN. *International Journal of Agriculture and Crop Sciences*, 4 (23), 1767–1777.
20. Yakhin, S. V., & Burlaka, O. A. (2020). Research on the influence of the operating modes of combine harvester's transportation lines on the quality of grain threshing. *Scientific Progress & Innovations*, 3, 269–279. https://doi.org/10.31210/visnyk2020.03.31
21. Burlaka, O. A., Yakhin, S. V., Padalka, V. V., & Burlaka, A. O. (2021). 100 tons per hour, what is next? Let us compare and analyze characteristics of the latest models of highly productive combine harvesters. *Scientific Progress & Innovations*, 3, 274–288. https://doi.org/10.31210/visnyk2021.03.34

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