

Conclusion

1. As the performed research shows, the most important factors that influence the effectiveness of the organization and management of work of modern combine harvesters include: optimal use of the operating speed and optimum utilization of the width, which "weight" is over 15 % and the average value of priorities is 7,55 % .

2. Then the next important factors include: compliance with terms and selection of maintenance engineering supporting, where, "weight" is 10,63 % and the average value of the priority of 5,31 %.

3. Other factors did not significantly affect the efficiency of work of combine harvesters; even though their "weight" is 34,3 % and 39,95 % are the average priority value amounts to only 4,29 % and 3,07 %.

Literature

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THE ANALYSIS OF SELECTED AGRICULTURAL TRACTORS MANUFACTURERS' OFFER AVAILABLE IN POLAND, IN TERMS OF TECHNICAL SOPHISTICATION

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Summary: *Offer of selected manufacturers of agricultural tractors available in Poland was presented. The analysis was made taking into account the criterion of technical sophistication of tractors. It can be concluded that foreign manufacturers have both less and more technologically advanced technologically models in their offer. In addition to the same extent of power, models of tractors from the same manufacturer differ in technical sophistication.*

Introduction

Tractors in modern agriculture are a major source of energy both in field work and in transport of agricultural products. The correct choice of the tractor has a major influence on the costs of performed agrotechnical works. It is possible only if the full range of tractors available in the market is known. Due to the fact that the technical advancement of tractors has an impact on the cost

of the agrotechnical work, the analysis of the manufacturers' offer in terms of the availability of tractors equipped with the latest technology becomes a necessity. Full knowledge of the available tractors allows you to effectively choose the optimum tractor for the farm.

Purpose, scope and research methodology

The aim of this study was to analyse the available offer of agricultural tractors in Poland, manufactured by leading producers, in terms of their equipment with modern technology.

Analyses were performed on the offer of selected tractor manufacturers available in the market in Poland in terms of technical sophistication of engines, power transmission system, PTO and hydraulic system.

The analysis was made using the information contained in the informational materials and websites of manufacturers and the agricultural press. For this purpose, a division of tractors on the low-, medium- and highly-technology advanced has been made. The group of tractors with a low technical advancement included only models equipped with mechanical assemblies. The group of tractors with medium technical advancement included models that have mechanical assemblies and assemblies electronically controlled by an operator. The group of tractors with high technical advancement included models equipped with fully electronically operated assemblies with the possibility of controlling the parameters of their work without an operator.

Characteristics of modern solutions used in agricultural tractors.

For many years, the offer of tractor manufacturers, also available in the Polish market, one has recognized the presence of models equipped with the latest design solutions. Significant progress is taking place in the tractor engines, which must meet stringent emission standards. Thus, in modern engines systems for exhaust gas recirculation (*EGR Exhaust Gas Recirculation*) or selective catalytic reduction systems (*SCR Selective Catalytic Reduction*) are used.[1].

An increasingly common solution used in the engines is Common Rail high-pressure injection system [4, 5, 6, 7, 8].

Currently used tractor engines, which meet the European *Stage III B* standard, are units equipped with a turbocharger (*VGT Variable Geometry Turbocharger*) with variable geometry of turbine wheel blades [4,5,6,7,8].

The specificity of engine equipment in terms of technological advancement has been shown in Table 1.

Technical advancement of tractors is largely visible in control systems. Currently, in low-advanced designs of tractors one uses synchronized gearboxes and in medium-advanced ones PowerShift gearboxes, which allow a change of gears without using the clutch master. In modern propulsion systems, one uses continuously variable transmission (CVT) [2]. Another known example of the infinitely variable gear transmission is Vario gearbox, used in Fendt tractors. A similar solution is used in Dyna-VT gearboxes in Massey Ferguson tractors of 7400 and 8400 series [7].

Table 1

Characteristics of technological advancement of tractor engines available in Poland

	Technical advancement of the engine		
	LOW	MEDIUM	HIGH
Number of valves in the cylinder	2	2 or 4	4
Injection type	mechanical	CommonRail	A. CommonRail fully electronic fuel injection and electronic control of the individual injectors B. CAT HEUI injection system (hydraulic electronic unit injectors)
Supercharger and air cooling	mechanical turbocharger with intercooler boost	variable-geometry turbocharger with charge air cooler	variable-geometry turbocharger with intercooler Reversing fan
Flue gas treatment	exhaust gas recirculation (EGR)	exhaust gas recirculation (EGR)	exhaust gas recirculation (EGR)

The specificity of propulsion system equipment in terms of technological advancement has been shown in Table 2.

Table 2

Characteristics of technological advancement of propulsion system used in tractors available in Poland

	Technical advancement of the propulsion system		
	LOW	MEDIUM	HIGH
Switching of four-wheel drive	mechanical	electro-hydraulic	electro-hydraulic automatic switching
Switching of differential lock	mechanically	electro-hydraulic	electro-hydraulic automatic switching, cooperation with on-board management system
Gearbox	Mechanical synchronized, mechanical reverse	A. Mechanical synchronized, mechanical reverse B. Semi-automatic transmission with automatic gearbox functions C. Stepless Vario transmission D. CVT stepless transmission	A. automatic switch for 4- 6 speed ranges with variable reverse drive switching modules, automatic speed matching B. fully automatic transmission and cruise control, gear shifting, depending on the speed control lever position and engine load, during transportation and field work C. Stepless Vario transmission

Differentiation of technical sophistication is also present in the hydraulic system and PTO. In the low-advanced designs, the control of these systems is done by mechanical means. However, more advanced tractors are equipped with electro-hydraulic control systems (e.g., EIIR). Standard in these structures is a tandem pump with an electronically controlled variable performance. In a

highly advanced tractor designs, an electronic control separate control of external hydraulic valves is used.

PTO drive in low-advanced tractors is mechanically switched, while in medium and highly advanced tractors it is electro-hydraulically switched. Similarly to the power transmission system in high-tech tractors, there is a possibility of programming work parameters of the hydraulic system and PTO.

The specificity of hydraulic system equipment and PTO in terms of technological advancement has been shown in Table 3 and 4.

Table 3

Characteristics of technological advancement of hydraulic system used in tractors available in Poland

	Technical advancement of hydraulic system		
	LOW	MEDIUM	HIGH
Control / regulation	A. mechanical B. mechanical control system with sensors of depth	electronic (EHC orEHR) adjustment of lift with amortization	A. electronic EHC) adjustment of the lift with lift amortization B. The rear lift electro-hydraulic lift EHR steering in the cabin and rear fenders electronic control system of draft (Electronic Draft Control, EDC)
Hydraulic Pump	tandem pump with fixed displacement	tandem pump with fixed displacement	tandem pump with variable flow rate - Load- sensing type
Additional equipment		Electronic measurement of resistance in the lower links of rear lift	Electronic measurement of resistance in the lower links. Vibration dampening system for lift electro-hydraulic valves. Joystick operated

Table 4

Characteristics of technological advancement of PTO used in tractors available in Poland

	Technical advancement of the PTO		
	LOW	MEDIUM	HIGH
Control	mechanical	A. mechanical B. electro-hydraulic Automation of actions on the field headland	electro-hydraulic automatic soft start, automatic feature, turning on from the outside, the electronic speed selection, automation of activities in the field headland

Offer of tractor producers in Poland, in terms of technical sophistication

One of the leading manufacturers, which in 2009 reached the highest level of sales of tractors in Poland, is New Holland [3]. It offers models in power ranges from just 35 hp to 395 hp, in the Polish market. The strongest tractors are in the T9000 series, however more popular are equally high-powered T8000 Series tractors with the power up to 325 hp.

Low-advanced tractors are offered with mechanically controlled engines and mechanical gearboxes of Shuttle Command™ type, with the number of gear ratios up to 24. Medium-advanced tractors have engines with CommonRail injection system and the gearboxes of Powershuttle type [4]. Switching of the front drive, differential lock and PTO is performed electrohydraulically.

The most advanced models are T7000 and T8000 series. They are equipped with computer management systems of tractor's engine operating parameters.

Table 5

Characteristics of New Holland tractors in terms of technical sophistication

		Technical advancement of the tractors		
		LOW	MEDIUM	HIGH
Power Range IHP ¹		35-113	101-165	143-395
Available models (horsepower; hp)		<p>A. T3000 T3010(35), T3020(43), T3030(48), T3040(54),</p> <p>B. T4000 Deluxe T4020(65), T4030(78), T4040(86), T4050(97),</p> <p>C. TD5000 TD5010(60), TD5020(72), TD5030(82), TD5040(88), TD5050(95),</p> <p>D. T5000 T5030(76), T5040(86), T5050(97), T5060(106), T5070(113)</p>	<p>A. T6000 Delta T6010(101), T6020(112), T6030(117), T6050(126),</p> <p>B. T6000 Plus T6010(101), T6020(121), T6030(117), T6050(126), T6070(141),</p> <p>C. T6000 Elite T6020(111), T6040(122), T6060(132),</p> <p>D. T6000 PC/RC T6030(117), T6050(127), T6070(142), T6080(155), T6090(165)</p>	<p>A. T7000 AC T7030(167), T7040(182), T7050(197), T7060(213), T7070(225),</p> <p>B. T7500 T7510(143), T7520(154), T7530(163), T7540(179), T7550(197),</p> <p>C. T8000 T8020(248), T8030(273), T8040(308), T8050(325),</p> <p>D. T9000 T9020(246), T9030(283), T9040(321), T9050(358), T9060(395),</p>

Source: own study based on New Holland Polska materials

Another very well known tractor manufacturer in Poland is John Deere. The most popular John Deere tractors are available in power range from 83 to 155 hp at the medium technical advancement level. Gearboxes in these tractors are available in typical mechanical versions (SyncReverser) and with electrohydraulic switching (PowrReverser). Hydraulic steering is done by the EHR which is a standard equipment [5].

Highly advanced tractors are represented in the 7030 series, equipped with systems that perform a similar function as similar class New Holland tractors.

CASE tractors are offered in a wide range of power. Small models used for light works, versatile tractors for small farms and processing of green areas are available in 5 models of tractors Case IH JX. Case IH JXU series comprises of a medium-sized tractors, universal in agriculture, which can be productive in cultivation and care works. While the Case IH CS PRO series (versatile tractors, better equipped) is able to achieve on-road speed of 40 km/h. All of

these series by Case manufacturer are fitted into technically low-advanced. They have the power in the range of 60-113 hp [6].

Table 6
Characteristics of John Deere tractors in terms of technical sophistication

		Technical advancement of the tractors		
		LOW	MEDIUM	HIGH
Power	Range	55-100	83-155	165-345
[HP]				
Available models		A. SERIES 5E	A. SERIES 6030	A. SERIES 7030
(horsepower; hp)		5055(55), 5065(65), 5075(75), B. SERIES 5G 5080(80), 5090(90), C. SERIES 5M OOS 5085(85), 5095(95), D. SERIES 5M 5070(70), 5080(70), 5090(90), 5100(100), E. SERIES 5R 5080(80), 5090(90), 5100(100)	6130(83), 6230(95), 6330(105), 6430(115), 6530(120), 6630(130), 6830(140), 6930(155), B. SERIES 6030 PREMIUM 6230(100), 6330(110), 6430(120), 6530(120), 6630(130), 6830(140), 6930(155)	7730(190), 7830(205), 7930(220), B. SERIES 7030 PREMIUM 7430(170), 7430E(165), 7530(185), 7530E(180) C. SERIES 8R 8245(245), 8270(270), 8295(295), 8320(320), 8345(345) D. SERIES 8RT 8295(295), 830(320), 8345(345)

Source: own study based on John Deere Polska materials

The more technologically advanced tractors from the same manufacturer are available within the Case IH Maxxum, series - multi-purpose tractors with a standard cabin profile, suitable for many works on the farm. A Case IH multicontroller series comprises of simple tractors with low profile cabin, universal in every farm, manoeuvrable in farm buildings. Case IH CVX series comprises of tractors, which reach on-road speeds up to 50 km/h. have more power and larger dimensions. Case IH CVX PUMA and PUMA CVX series comprises of new models with small turning radius, which is suitable for basic work on the farm such as cultivation, sowing, and transport.

The largest and most well equipped series of tractors is Case IH, while the most powerful series of tractors are Case III Steiger and Quadtrac [6].

In the Claas company's offer, the tractors with the lowest power and smallest technical advancement are in Axos and Ares series, used on smaller farms with animal husbandry, cultivation and care of plants. Higher class tractors are within Arion and Arion C series, which are characterized by better equipment and more power. These tractors are used as more universal tractors in farms as well as in the construction of roads, highways and transport. The highest power tractors of Claas manufacturer are in Axion and Xerion series; these are the vehicles with the greatest technical advancement. There are infinitely variable transmissions used e.g. CMATIC, as well as the ZF Ecom 3.5 continuously variable transmission (in Xerion tractor), which allows you to switch to 4 ranges in both directions of travel without interrupting the drive [9].

Table 7

Characteristics of Case tractors in terms of technical sophistication

		Technical advancement of the tractors		
		LOW	MEDIUM	HIGH
Power Range [HP]		60-113	101-224	224-548
Available models (horsepower; hp)		A. JX 60(60), 70(72); 80(82), 90(88), 95(95); B. QUANTUM 65C(65), 75C(78), 85C(86), 95C(97), C. JXU 75(75), 85(85), 95(95), 105(105), 115(113); D. CS Pro 85(85), 95(93), 105(102),	A. MAXXUM 100(101), 110(112) 115(117); 125(126), 140(141) B. MAXXUM multicontroller 110(112), 115(117), 120(122), 125(127) 130(132), 140(140) C. CVX 140(141), 150(150), 160(160). 175(175), 195(196) D. PUMA 125(127), 140(142), 155(158), 165(167), 180(182), 195(197),210(213) E. PUMA CVX 195(197), 210(213), 225(224)	A. MAGNUM 225(224) 250(251), 280(279), 310(309), 335(335) B. STEIGER 385(394), 435(444) C. QADTRACK 385(394), 435(444), 485(496), 535(548)

Source: own study based on CNH Polska materials

Table 8

Characteristics of Claas tractors in terms of technical sophistication

		Technical advancement of the tractors		
		LOW	MEDIUM	HIGH
Power Range [HP]		74-100	110-180	169-344
Available models (horsepower; hp)		A. AXOS 310(74) 320(86), 330(90), 340(100); B. ARES 547(90), 557(100), 567(110)	A. ARION 410(95), 420(105), 430(115), B. ARION CIS 410(95), 420(105), 430(115), C. ARION 510(110), 520(120), 530(130), 540(135), 610(120), 620(135), 630(145), 640(155), D. ARION C 610(120), 620(135), 630(145)	A. AXION 810(169), 820(189), 830(203), 840(212), 850(233) B. XERION 3300(305), 3800(344)

Source: own study based on Claas Polska materials

Fendt tractors are considered to be one of the upper class tractors. The technical solutions used in these tractors are primarily: Vario continuously variable transmission, which is installed in almost all models of the Fendt brand. Modern technologies, comfort and quality finish affect high scores and high practicality.

The manufacturer, especially for connoisseurs, offers beautiful colour versions of its tractors. The most luxurious and powerful tractors are within the "BLACK BEAUTY" series [8].

Table 9

Characteristics of Fendt tractors in terms of technical sophistication

		Technical advancement of the tractors		
		LOW	MEDIUM	HIGH
Power Range [HP]		65-110	95-180	185-360
Available models (horsepower; hp)		A. 200S 206(65), 207(75), 208(86), 209(95), B. 200Vario 207(70), 208(80), 209(90), 210(100), 211(110)	A. 300Vario 309(95), 310(105), 311(115), 312(125). B. 400Vario 411(115), 412(125), 413(135), 414(145), 415(155) C. 700Vario 712(130), 714(145), 716(165), 718(180).	A. 800Vario 818(185), 820(205), B. 900Vario 922(220), 924(240), 927(270), 930(300), 933(330), 936(360),

Source: own study based on DHK Korbanek materials

Conclusion

The offer of agricultural tractors manufacturers in Poland is very broad. Buyers can enjoy a wide range of tractors of varying degrees of technical sophistication. They can choose low-tech constructions, with the fact that these are models with lower capacities. Models with higher power are offered in medium- and high-tech versions. Versions of the medium-tech tractors are often characterized by the engine with electronic injection system, controlled by electro-hydraulic drive system and an external hydraulic system. High-tech tractors are characterized by electronic and electro-hydraulic units control as well as the presence of computer management systems.

The analysis of the offers of selected manufacturers shows that in each group of technical advancement there are a few or even a dozen models of tractors. The most diverse group of manufacturers' offer comprises of medium-tech tractors.

Literature

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