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STUDIES ON THE DYNAMICS OF THRESHING APPLIANCES OF CEREAL HARVESTING COMBINES

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Abstract

The present paper presents a comparative study of the threshers that equip different types of self-propelled combines for cereal harvesting. Particular attention is paid to the problems related to the exploitation of the threshers, focusing on some more important aspects, including those regarding the technological adjustments, the organization and management of the harvesting chain, the execution of the harvesting works and their quality control. We measured the constructive and functional parameters of each threshing device and determined the hourly productivity of each combine and the consumption of diesel per ton of harvested wheat. This shows that worldwide harvesting combines tend to use double-flow threshers with tangential flow due to the following advantages: both threshing and separation of the grains from the straw are done, both length of the thresher and vibrations are reduced because there is no shaking for separation, the percentage of non-threshed ears is reduced by the fact that the material is trained in rotary motion inside the threshing device.

Key words: *thresher, self-propelled combines, harvesting works, constructive parameters, technological adjustments.*

INTRODUCTION

Combine harvesters in use today can achieve production rates of over 70 t/h of grain; however, their technical performance potential is currently, by no means, exhausted. This paper describes the global combine harvester market, its inventories and recent productions. According to the distribution of farm size and regional field sizes, Germany was divided into three combined cropping regions. Simulation results show that about 45,000 units of agricultural combines of three performance categories are needed in Germany. However, calculations show that future domestic sales of combine harvesters will largely depend on the lifetime of the units (Clemens et al., 2015).

As stated by Kutzbach & Quick (1999), the main processes in a modern harvester are gathering and cutting, threshing, separating, cleaning, and material handling. Currently, designers of the combine harvesters pay more attention to the improvement of the quality of the control process and of its automatic control, and they improve the trafficability of the chassis and the environment protection. They argue that an increase in engine power increases the throughput of the combine harvester. (Kutzbach & Quick, 1999). Combine harvesters with axial threshing-separating device are, after design improvement of the axial drum, increasingly used for the harvest of the grain crops and rape with increased grain moisture content (Špokas, 2005; Špokas, 2006). Currently, the combine harvesters equipped with the straw walker with medium capacity are prevailing. Grain losses and grain damage are used as basic indicators for the evaluation of their technological function (Eimer, 1988; Feiffer et al., 2005). The working capacity of conventional grain harvesters is mainly determined by the working capacity of the tangential threshing machine.

Its working capacity depends on both the technical and functional characteristics of the actual tangential threshing machine and the biological characteristics of the harvested plant mass (Chirilă, 2012). The piece of material driven by a rail of the beater is rolled in the threshing space and, under the action of frictional and centrifugal forces, the material is combed and the seeds are separated (Ivan & Vlăduț, 2014). What mainly characterises the major differences in the technological flows of the current grain harvesters is the type of systems for picking up the material from the field and the construction of the threshing bodies. The vast majority of combines currently use traditional (tangential) threshers with a single beater, but the current trend is to use combines equipped with axial threshers or with multiple beaters/threshing rotors and separation, which aim to increase working capacity.

According to the technological flows, the combines are divided into two categories:

-Combines with tangential threshing machines, where the transverse threshing machine is located immediately after the central conveyor, the material flow entering perpendicular to it, and the material taken from the screw conveyor and placed in the centre where the threshing machine is located hits the bars (rails) beating roughly tangentially;

-Combines with axial threshing machines, where the thresher is located axially on the longitudinal axis of the thresher and, in some cases, the transverse flow of the material moves through the thresher on a helical path, and the material is separated mainly due to the friction and forces of the centrifuges and less to collision (Chiril et al., 2011).

The threshing device of conventional grain harvesters is of the tangential type.

This is the main working organ of these combines in terms of seed separation and energy consumption (Kutzbach, 2003).

The tangential threshing device is positioned in the technological flow of the conventional grain harvester between the central elevator and the shaker.

The axial thresher is a more recent achievement, being introduced in the construction of grain harvesters in 1970, especially in the construction of grain corn harvesters, later extending to straw grain harvesters as well (Ivan, 2009).

Under optimal conditions, the separation of seeds in the tangential thresher can reach a maximum of 85%, falling below 50-60% in case of improper adjustments and of a crop with high humidity (Miu & Kutzbach, 2008).

The tangential thresher must ensure a threshing process with unthreshed seeds and remaining in ears below 1%, free seeds in straw below 14% and damaged seeds below 2% of the harvested production (Segărceanu, 1990).

In a tangential feed axial threshing unit, the grains begin to separate through the cage openings as they become free.

Such threshing units are used in combines designed by the German manufacturer CLAAS® that are used worldwide (Miu, 1995).

In this context, the scientific organization of the harvesting of grassy cereals can result in a shortening of the harvesting period by 20-25% and an increase in labour productivity by 24%.

In order to achieve these targets, as well as for the rational operation of the combines, it is necessary to take a series of organizational measures: preparing the field for harvesting, choosing the methods of moving the combine in the field, and ensuring the means of transport.

Threshing is the most important function of grain harvester.

Grain loss and damage in harvesting are significantly related to threshing theory and technology.

There are four kinds of threshing principles including impact, rubbing, combing and grinding.

Four types of contact models between grain and threshing components have been constructed correspondently.

Grain damage can be regarded as a function of peripheral velocity and contact pattern of impacting.

Grain loss can be regarded as a function of contact pattern of rasp bars.

Grain loss coming from cleaning and separation in the subsequent process of combing threshing was significantly decreased.

Tangential and axial threshing technologies have been applied in grain threshing system widely.

It showed that in the combined application, tangential rolls are used to accelerate grain flow, and axial rolls are used to increase threshing quality especially lower loss and damage.

Conical concave may take the place of the traditional cylindrical one. With the development of sensor technology and communication technology, intelligent harvesting robot and automatic threshing system will be integrated together to improve grain quality and operation comfort (Jun Fu et al., 2018).

The statistic proposes the analytical provisions and the experimental results of the throughput capacity of the threshing apparatus of grain harvesters, from the capacity of straw, grain, straw content, blockage of design characteristics.
The threshing capacity is most significantly affected by weediness due to humidity, with a relative weediness of 0.05 bread weight, the capacity of the threshing machine is reduced by 2.5%, and with 50% weed by 16%.
Loading of the threshing machine determines the productivity of the combine and fuel efficiency due to fuel consumption for harvesting 1 hectare, as well as threshing 1 ton of crop.
The power of the combine engine is designed to perform work in extrem econditions, as a result, the average loadis 2/3 of full.
During the operation of the combines, the time is only 45-50% of the total operating time of the engine. Underemployment of the engine leads to overconsumption of fuel.
So, if the SMD-21M diesel at full operational power of 103 kW consumes fuel of 0.24 kg on 1 kW for an hour, at loading on 50% 51 kW s. specific fuel consumption increases by 41 g/kWh, or 17%, which corresponds to fuel consumption 2.1 kg/year (Rogovskii et al., 2020). The technological process of separation of the grain pile from large impurities (spikelets, straw remnants, etc.) and light impurities (husks, small weed seeds, etc.) in combine harvesters (CH) occurs in the cleaning system by air-sieve.
The existing air-sieve cleaning systems have a number of significant drawbacks as to the quality of the implementation of the technological process of separation of the grain pile from impurities. This is due to the increase in throughput, uneven ripening of the grain mass, unevenness of grain entering the cleaning, different concentrations of grain particles (grain and impurities), moisture and grain contamination, uneven distribution in width when harvesting on slopes. This is due to the unevenness or violation of the uniform distribution of the air flow over the entire area of the sieves due to the imperfection of the existing structures of the cleaning system, as well as the lack of a complete theoretical description and methods to substantiate their structural and technological parameters (Mudarisov et al., 2017).

MATERIALS AND METHODS

For the study of the dynamics of threshing machines, two constructive types of self-propelled combines for harvesting straw grain were chosen - one with a tangential threshing machine (with beating rails) and one with an axial threshing machine.
These studies were carried out at agricultural farms in Timiș County (Carani, Bărăteaz) and Caraș-Severin County (Nicolinț), both in Romania.
The constructive and functional parameters of each threshing machine ere measure to determine the hourly productivity of each combine and diesel consumption per ton of harvested wheat.
The self-propelled combines on which these studies were carried out are:
- The Claas Lexion 750 self-propelled combine harvester;
- The John Deere S 670i self-propelled combine.

RESULTS AND DISCUSSIONS

The Claas Lexion 750 self-propelled combine harvester is equipped with a Mercedes-Benz OM 470 LA diesel engine with a total displacement of 10.7 l.
The diesel tank has a volume of 800 l, and the engine complies with Tier 4f pollution standards. The threshing machine of this combine is of the APS Hybrid type, with pre-separation accelerator.
The advantages of this threshing system are the following:
- The plants harvested and transported to the thresher first reach the pre-accelerator, which increases the material supply speed of the threshing machine from 3 m/s to 12 m/s;
- The speeds of the three drums (accelerator, beater, and post-beater) can be adjusted independently depending on the threshing conditions;
- The harvested material moves at a higher speed between the rotors;
- The centrifugal forces increase due to the increased speed of the material, which helps

separate the grains from the threshed ears faster;
- The beater's load is reduced by 30% because part of the grains is threshed by the pre-separation rotor;
- The closed beater of the tangential threshing machine ensures smooth threshing for any type of culture;
- The feed flow of this threshing system increases by about 20% for the same diesel consumption;
- It is the most efficient threshing system for the cultivation of wheat.

The measurements of the threshing system of this combine were processed, interpreted and centralized in Table 1.

Table 1. Measurements obtained on the Claas Lexion 750 self-propelled combine harvester

Parameter	UM	Value
Beater diameter	mm	600
Beater width	mm	1420
Beater speed	rot./min	450-1050
Beater angular speed	rad./sec	46-108
Centrifugal acceleration	m/s^2	635-3498
Thresher cinematic index	K	64-357
Counter-beater wrapping angle	degrees	142
Counter-beater area	m^2	1.45
Thresher feeding flow	kg/sec	22
Hourly combine productivity	t/h	48

The John Deere S 670i self-propelled combine is equipped with a 465 HP diesel engine.

The axial threshing device of this combine has a single rotor "Single Tine Separation - STS" and fulfils both the role of threshing and that of separating unthreshed seeds and ears from the top of the material.

The rotor of the threshing machine, of a special construction (bullet rotor), is equipped with beating bars on the front section and with separation fingers on the rear section.

The separation cylinder on the outside of the rotor is divided into three concentric sectors, the first sector having the smallest diameter and the last sector having the largest diameter.

The concave separation grates are very easy to replace when changing from one crop to another.

Due to the concentricity of the three separation sectors, the material is driven tangentially and longitudinally in the separation space.

The gradual opening of the separation diameter allows the flow of material to move by expansion from the entrance to the exit of the separation "cage".

The separation surface is larger, the centrifugal forces are increasing, the movement of the rotor is continuous and uniform and, as a result, the quality of the process of separating the grains from the straw is superior compared to the classic separation systems.

Thanks to this special construction, the material does not agglomerate inside, the evacuation from the rotor is relatively easy, and there is, practically, no possibility of clogging the device with material.

Due to the expansion movement of the material, it is energetically loosened and, therefore, harvesting is possible even at higher humidity. Also, due to the increase in centrifugal forces, the process of forced separation of the grains from the straw intensifies.

The technical characteristics of the threshing machine of the John Deere S 670i self-propelled combine are presented in Table 2.

Table 2. Measurements obtained on the John Deere S 670i self-propelled combine

Parameter	UM	Value
Rotor diameter	mm	762
Rotor length	mm	3124
Rotor speed	rot./min	210-1000
Rotor angular speed	rad./sec	22-105
Centrifugal acceleration	m/s^2	193-4410
Thresher cinematic index	K	20-448
Counter-beater wrapping angle	degrees	124
Counter-beater area	m^2	1.54
Thresher feeding flow	kg/sec	21
Hourly combine productivity	t/h	42

In this paper, two types of threshing machines are analysed:
- The tangential threshing machine in the Claas Lexion 750 self-propelled combine harvester;
- The axial threshing device in the John Deere S 670i self-propelled combine.

The parameters of the threshing apparatus, from the two types of self-propelled combines for harvesting cereals, are centralised in Table 3.

Table 3. Parameters of the threshing apparatuses studied

Parameter	UM	Self-propelled combine	
		Claas Lexion 750	John Deere S 670i
Beater / rotor diameter	mm	600	762
Beater width, Rotor length	mm	1420	3124
Beater speed	rot./min	450-1050	210-1000
Beater angular speed	rad./sec	46-108	22-105
Centrifugal acceleration	m/s^2	635-3498	193-4410
Thresher cinematic index	K	64-357	20-448
Counter-beater wrapping angle	degrees	142	124
Counter-beater area	m^2	1.45	1.54
Thresher feeding flow	kg/sec	22	21
Hourly combine productivity	t/h	48	42

CONCLUSIONS

The study on the dynamics of the threshing machines of the grain harvesters was carried out on a number of two combines: one with tangential flow and one with axial flow.

From the analysis of the technical characteristics of the threshing apparatuses of these self-propelled combines, the following conclusions can be drawn:

- The Claas Lexion 750 self-propelled combine is equipped with a tangential flow thresher with APS pre-pressing accelerator and Multicrop type counter-balancer.

The double threshing surface - a pre-separation grate and a Multicrop counter-beater - make the thresher highly productive, reducing energy and fuel consumption.

- The John Deere S 670i self-propelled combine is equipped with an axial thresher with a single rotor (bullet rotor).

The separation cylinder on the outside of the rotor is divided into three concentric sectors of different diameters.

Due to this special construction, the material does not agglomerate inside the cylinder and there is no risk of clogging the device with material.

Due to the expansion movement of the material, it is energetically loosened and, therefore, harvesting is possible even at higher humidity.

Therefore, it can be seen that grain harvesters tend to use double threshers with tangential flow and threshers with axial flow, due to the following advantages: both threshing and the separation of grain from straw are achieved; the length of the coulter and the vibrations are reduced since the shaker is no longer used for separation; and the percentage of unthreshed ears is reduced because the material is driven in a roto-translational movement inside the threshing machine.

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