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THE INFLUENCE OF GEOMETRY OF THE WORKING ELEMENTS OF THE PADDLE CONVEYOR ON GRAIN DAMAGE

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A b s t r a c t. The results of comparative studies of paddle grain conveyors of combine-harvester are presented. One of them was a conveyor which has been used so far in BIZON combine-harvester; the other one was a modified conveyor intended for combine-harvesters of higher capacity in which other dimensions of paddles and working channel were used. The research was done on a specially built research post which ensured the regulation of exploitation parameters of the conveyors under discussion. The influence of the construction of conveyors on capacity, the filling coefficient and micro- and macro-damage of the shifting grain were defined. The study proved that the modified conveyor achieved higher capacity with higher filling coefficient of working space. Thanks to better filling of the conveyor, grain underwent smaller mechanical damage.

K e y w o r d s: wheat grain damage, combine-harvester, paddle conveyor

INTRODUCTION

The system of internal grain transportation belongs to the basic working sets of grain combine-harvester side by side with a harvesting and threshing sets. Modern constructions of combine-harvesters usually possess a paddle-screw set of internal transportation. The conveyors commonly used nowadays, beside many advantages have numerous disadvantages like causing mechanical grain damages lowering its biological value. Moreover, these conveyors working with a considerable inclination are characterized by relatively low productivity and that is why they do not secure proper work of a combine-harvester with higher capacities. In order to increase productivity of a combine-harvester, its pad-dle grain conveyor has been modernized for a combine-harvester of productivity up to 20 kg/s of grain mass.

The modernized and traditionally used systems of grain transportation have been compared by means of stand testing. This paper comprises the results of testings referring to the amount of micro- and macro-damages caused in the process of grain transportation and the value of filling coefficients determining productivity of conveyors.

The aim of this work was a comparison of tested sets of transportation. The criteria assumed for the evaluation were as follows: the amount of mechanical grain injuries caused in the process of transportation, productivity and the value of filling coefficient of the working space of the conveyors.

MATERIAL AND METHODS

The characteristics of the tested object

Two sets of grain transportation were examined. One of them was a system of grain transportation used in combine-harvester Bizon Z056 and previous models of these machines.

The other one was a modernized set of grain transportation produced in the Institute of Agriculture Mechanization of the University of Agriculture in Lublin. Both sets of grain transportation were installed on a testing stand presented in Fig. 1.

With the usage of bibliographical data, optimum size of side and frontal plays were chosen between the paddles edges and the

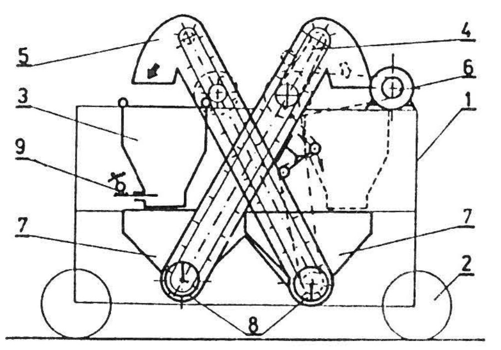


Fig. 1. Scheme of a stand for testing grain conveyors: 1 - frame of the stand, 2 - vehicular system, 3 - charging hopper, 4 - paddle conveyor, 5 - modernized conveyor, 6 - power transmission system, 7 - charging hoppers, 8 - screw powering conveyor, 9 - batcher.

walls of the working canal. Moreover, the proportion of width to height of the paddles was properly chosen [2-5]. More important data characterizing the construction of the conveyors under discussion are presented in Table 1.

The conditions and methods of the testings

The general methodological assumptions covered:

- the method of capacity measurement a definition of a filling coefficient of the working space of the conveyors,
- the method of definition of mechanical damage (micro and macro) of the transported grain,
- the analysis of the results of the testings and a measuring error.

Stand testings were conducted with transportation of wheat grain Grana variety of 15.7 % moisture content. During the testing a step change of speed of the paddles was applied every 0.25 m/s in the range of 2.25-3.0 m/s. Different angles of inclination of the conveyor were used and side inclination - β within the limits $\pm 15^{o}$ in relation to the initial (normal) position.

Particular measurements were done after the continuous stream of grain was obtained, characterizing work of the sets close to maximum productivity in the assumed conditions. Grain mass - m was defined by means of a scale exact to ± 50 g.

The value of filling coefficient for particular measurements and positions of the conveyor was defined as:

$$\Psi = \frac{m}{F \cdot v \cdot \zeta \cdot t} \tag{1}$$

where F - intersection area of the working canal, m - grain mass transported in time, t - time of the testing, v - paddles speed, ζ - grain density in chute state.

Definition of the amount of grain with macro-damage depended on manual separation of injured grains out of 100 g sample and definition of its mass and percentage.

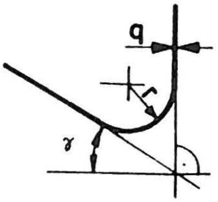
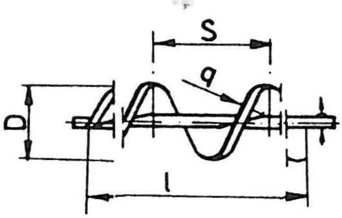
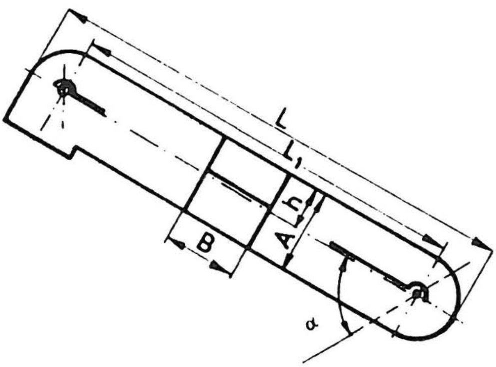
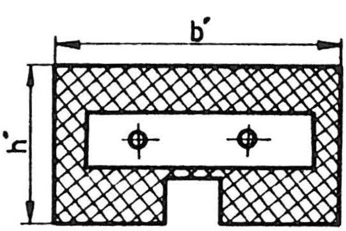
The results obtained were subjected to statistical analysis using ANOVA-method (the analysis of variance) for a four-way, orthogonal experimental design. Importance of the influence of tested factors was verified by means of testing function F_0 - Snedecor, whereas T - Tukey's confidence intervals were used for estimation of the significance of differences between different means [1]. Relative error analysis was done by means of differentiation method [6].

RESULTS AND DISCUSSION

Combine-harvesters are used on fields of different configurations. That is the reason why grain conveyors in a combine-harvester work in extremely unfavourable and variable settings. Two constructional aspects are generally responsible for that. One, that is a considerable leaning of paddle conveyor of grain. The conveyor working on flat surfaces is inclined at the angle of 60^{o}. Taking into account 15^{o} of a combine-harvester inclination resulting from the relief of the area, conveyors have to ensure continuity of the technological process in the range of inclinations 45^{o}-75^{o}.

The other factor determining the work of the first conveyor, is the method of powering of a paddle conveyor. In modern constructions of combine-harvesters it is done

Table 1. Basic dimensions of the tested conveyors

Detail of the construction (working element)	Symbol	Unit	Type of conveyor	
			traditional	modernized
Screw conveyor trough	r	mm	75.0	85.0
	g	mm	3.0	2.0
	γ	...^{o}	60.0	60.0
Powering screw conveyor	D	mm	140.0	160.0
	S	mm	140.0	160.0
	d	mm	40.0	40.0
	q	mm	3.0	2.0
	l	mm	1600.0	2100.0
Working canal	A	mm	270.0	270.0
	L	mm	3148.0	3148.0
	L_1	mm	2827.0	2827.0
	h	mm	103.0	103.0
	B	mm	130.0	200.0
	q	mm	1.0	1.5
	α	...^{o}	60.0	60.0
Paddle	h'	mm	85.0	97.0
	b'	mm	110.0	190.0
	c=b':h'	-	1.3	2.0
	i	pcs	38.0	38.0
	q	mm	10.0	10.0
	side play	%	15.5	5.0
	frontal play	%	17.5	7.5

by means of a screw coil working in a casing (trough) and placed square to the paddle conveyor. Such constructional solution as a rule does not ensure work of the conveyor with a high filling of the working space. Work of the conveyor with a low value of a filling coefficient (Ψ) is characterized by low capacity (Q) and increase of mechanical damage ($U, \bar{u}$) in transported grain (Table 2).

The analysis of the construction of a traditional transportation set enabled proper choice of dimensions and shape of blades and the working canal in a modernized conveyor. As a result of the changes, a modernized

Table 2. Mean values of productivity (Q), filling coefficient (Ψ), macro- ($\bar{u}$) and micro- (U) grain damage obtained by a typical conveyor for different inclination angles (α), speed of the paddle shift (v) and angles of side inclination (β). Grain density - 709 kg/m^3, grain moisture content - 15.7%.

v (m s^{-1})	β (^{o})	α (^{o}) 45				60				75			
		Q (kg s^{-1})	Ψ	U (%)	$\bar{u}$ (%)	Q (kg s^{-1})	Ψ	U (%)	$\bar{u}$ (%)	Q (kg s^{-1})	Ψ	U (%)	$\bar{u}$ (%)
2.25	75	5.9	0.29	0.10	2.0	5.8	0.28	0.11	2.2	5.4	0.26	0.12	2.4
	90	5.4	0.26	0.12	2.0	5.2	0.25	0.13	2.4	5.0	0.24	0.13	2.4
	105	5.1	0.24	0.12	2.0	4.7	0.22	0.13	2.4	4.6	0.22	0.13	2.6
2.50	75	6.7	0.29	0.10	1.8	6.5	0.28	0.11	2.2	6.4	0.28	0.11	2.6
	90	6.5	0.28	0.11	2.2	6.3	0.27	0.11	2.0	6.0	0.26	0.11	2.6
	105	6.1	0.26	0.12	2.2	5.8	0.25	0.13	2.4	5.6	0.24	0.13	2.6
2.75	75	7.3	0.28	0.12	2.4	7.1	0.28	0.12	2.6	6.8	0.27	0.12	2.8
	90	7.0	0.28	0.12	2.6	6.9	0.27	0.13	2.4	6.5	0.26	0.13	2.8
	105	6.6	0.26	0.12	2.2	6.2	0.25	0.13	2.4	6.0	0.24	0.13	2.4
3.00	75	7.4	0.27	0.12	2.4	7.2	0.26	0.12	2.8	6.9	0.25	0.12	2.8
	90	7.1	0.26	0.12	2.6	7.1	0.26	0.12	2.8	6.8	0.25	0.12	2.8
	105	6.8	0.25	0.12	3.2	6.7	0.24	0.12	2.6	6.4	0.23	0.14	2.8

Table 3. Mean values of productivity (Q), filling coefficient (Ψ), macro- ($\bar{u}$) and micro- (U) grain damage obtained by a typical conveyor for different inclination angles (α), speed of the paddle shift (v) and angles of side inclination (β). Grain density - 709 kg/m^3, grain moisture content - 15.7 %.

v (m s^{-1})	β (^{o})	α (^{o}) 45				60				75			
		Q (kg s^{-1})	Ψ	U (%)	$\bar{u}$ (%)	Q (kg s^{-1})	Ψ	U (%)	$\bar{u}$ (%)	Q (kg s^{-1})	Ψ	U (%)	$\bar{u}$ (%)
2.25	75	10.2	0.32	0.10	1.8	10.2	0.32	0.10	2.0	9.7	0.30	0.10	1.8
	90	10.4	0.33	0.11	2.0	10.2	0.32	0.11	1.8	9.6	0.30	0.11	1.8
	105	9.7	0.30	0.11	2.0	9.5	0.30	0.12	1.6	9.3	0.29	0.12	1.8
2.50	75	12.9	0.37	0.09	1.6	12.9	0.37	0.09	2.2	12.2	0.35	0.11	1.8
	90	12.9	0.37	0.10	2.0	12.4	0.35	0.10	2.0	12.0	0.34	0.11	1.6
	105	12.4	0.35	0.11	1.8	11.7	0.33	0.12	1.6	11.6	0.33	0.12	2.2
2.75	75	14.5	0.37	0.09	2.0	14.0	0.36	0.09	1.8	14.0	0.36	0.10	2.0
	90	14.5	0.37	0.10	2.0	13.8	0.36	0.10	2.2	13.8	0.36	0.11	2.2
	105	13.5	0.35	0.11	1.6	12.8	0.34	0.11	2.4	13.6	0.35	0.12	2.0
3.00	75	15.2	0.36	0.09	2.0	14.6	0.34	0.11	1.8	14.0	0.33	0.12	2.2
	90	14.4	0.34	0.10	2.0	14.1	0.33	0.12	2.2	13.7	0.32	0.12	2.0
	105	14.6	0.34	0.11	2.2	14.0	0.33	0.12	2.0	13.3	0.32	0.13	2.2

conveyor in identical working conditions achieved twice as high capacity as a conveyor used so far. Values of a filling coefficient of a new conveyor were also higher at about 50 % in comparison with a traditional conveyor (Table 3).

Resulting from better filling of the working canal less mechanical damages of the transported grain were observed. Differences were observed primarily in the amount of micro-damages. Less effects were achieved while comparing the amounts of macro-damage (Tables 2 and 3).

CONCLUSIONS

The testings conducted proved that a change of the shape and geometrical dimensions of the working elements of the conveyor resulted in better parameters of its work. Work of a modernized transportation set was characterized by higher productivity and higher value of a filling coefficient - Ψ of the working space. Moreover, smaller amounts of micro- and macro-damages in the transported grain were observed.

It should be stressed that the results of the testings of the conveyors have been applied to the industry of agricultural machines. A modernized conveyor has been introduced into serial production. The conveyor is characterized by higher capacity and lower grain damages in transportation.

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