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MECHANICAL DAMAGE TO GRAIN IN MULTIDRUM THRESHING AND SEPARATING SETS*

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A b s t r a c t. The results of investigations of multidrum threshing and separating sets for threshing cereals are presented. A comparison of the work quality of these sets has been made on the basis of the amount of damage to grain separated.

K e y w o r d s: multidrum threshing and separating sets, damage to grain

INTRODUCTION

Mechanical damage to grain (micro- and macro-) decreases its biological value [4,8, 9,10,12-14]. The amount of damage, therefore, is often taken as a criterion of evaluation of the quality of threshing and separating sets. For this reason quantitative and qualitative evaluation of damage occuring during threshing are of the great importance. It is known from our own studies, and from the literature available, that grain is damaged in greater measure by multidrum threshing and separating sets than by threshers fitted with traditional straw walkers [2-6,8,9,14]. This results from the construction and the mechanism of grain separation. In threshers with multidrum separators the threshing set is equipped with a shortened concave. This separates only about 70-80 % of grain contained in the corn being threshed, and requires greater plant mass in comparison with a thresher fitted with a key shaker.

It should be emphasized that rethreshing and separating grain by separator drums results in an increase in the amount of mechanical damage to grain [2,5-7]. On the other hand, the traditional threshers of combine harvesters do not give throughput increase because of the limited effectiveness of the work of the machines straw walkers.

Taking into account that many scientists and constructors are interested in multidrum threshing and separating sets, three models of such sets were built in the Institute of Agricultural Mechanization of the University of Agriculture in Lublin and stand investigations were carried out [2,3,5,6].

AIM AND SCOPE OF WORK

The aim of this work was to define the amount of micro- and macrodamage to grain caused by multidrum threshing and separating sets during threshing and to explain the reasons and mechanisms of producing damage as well as the possibilities of their limitation.

One eightdrum and two threedrum threshing and separating sets were subjected to tests while threshing wheat, barley, rye and oats. The amount of mechanical damage to grain being threshed was estimated, at different technical parameters of working and at various plant moisture content.

CHARACTERIZATION OF RESEARCH OBJECTS AND INVESTIGATION CONDITIONS

The objects of the research were three models of multidrum threshing and separating

*Paper presented at 6 ICA

sets intended for combine harvester of higher capacity. A detailed description of these sets is presented in several papers [2,5,6]. The sets were installed on the research post enabling changes to the working parameters within the range given in Table 1.

METHODS

The methods of investigations covered:
- grain sampling and the definition of representative numbers,
- defining the physical and mechanical properties of cereals and the grain separated,
- defining the micro- and macrodamage to grain,
- the analysis of results obtained.

The sheafs of four varieties of cereals, gathered with a binder and randomly taken were the initial material intended for testings (Table 2). The chosen quantities characterizing the physical properties of the cereal mass were defined according to Polish standards.

The amount of macrodamage to grain produced during threshing was defined by comparing the mass of grain with macrodamage in the sample taken after threshing (100 g) with the mass of seeds with microdamage in a control sample (100 g). The grain for the control samples was taken from ears manually. Measurements were performed in five repetitions every time. The final result was an average of five measurements and was given in percentage by weigth.

The amount of microdamage to grain was also defined in five repetitions on the basis of the samples of one hundred seeds randomly taken. The number of seeds with microdamage was calculated in every sample, and the results were given in percentages.

To identify grains with microdamage the grain samples were dipped in Lugol's liquid (J+KJ). Lugol's liquid turns starch brown at the damaged points which are otherwise invisible [2,5].

The amount of microdamage was not defined for oat grain because its external husk protects it against microdamage.

The comparison of grain damage was made with a four-parameters variance analysis model, taking into account:
- capacity of threshing and separating sets, kg/s,
- angular speed of separating drums, rad/s,
- dimension of working clearence between separating drums and grids, mm,
- moisture content of grain, %.

The values of average damage were compared at different levels of the factors mentioned, using Tukey's multiple confidence intervals [1,11].

RESULTS

The quantities of grain damaged during threshing with a multidrum threshing and separating set are given in Tables 3-5.

The analysis of the results obtained shows that most grain damage occurs in the first two sections of separator irrespective of the construction of the separating set (eight - or threedrums) and the species of cereal [2,5,6].

Moreover, it was stated that the amount of micro- and macrodamage in separated grain depends on the type of separating set, and the sets adjusment parameters as well on the variety of cereal and its grain moisture content.

The tests proved that the amount of mechanical damage to separated grain was determined mainly by the number of active sections of separator. The eightdrum threshing and separating sets produced twice as much macrodamage and by 50 % more microdamage to wheat grain the threedrums separator.

From among the adjustment parameters the circumferential speed of separating drums and capacity mainly determined the amount of grain damage. The dimension of working clearence had a little less influence on the damage of grain.

It was also shown that the grain properties connected with the type of cereal and its moisture content determine the amount of damage to grain during threshing and separating. The grain of rye (Tables 4 and 6) and of wheat (Tables 3 and 5) proved to be the most susceptible to damage. For these varieties grain damage was most severe when threshing and

Table 1. Characteristics of technical and working conditions of investigations

Quality or parameter	Measure	Value
Cereal mass feeding system:		
Speed of feeding conveyer	m/s	1
Threshing set:		
Angular speed of threshing drum	rad/s	96.6
Circumferential speed of the rasp bars of threshing drum	m/s	29
Working clearence (input/output) for capatities:		
(2.5 and 4.0 kg/s) - S_1	mm	20/9
(5.5 and 7.0 kg/s) - S_2	mm	32/15
Separator:		
Angular (circumferential) speed of separating drums:		
ω_1 (V_1)	rad/s (m/s)	53 (10)
ω_2 (V_2)	rad/s (m/s)	78 (15)
ω_3 (V_3)	rad/s (m/s)	103 (20)
Working clearence between separating drums and grids	mm	25 and 40
Inclination angle of separating set frame	...^{o}	15

The characterization of cereals threshed is placed in Table 2.

Table 2. Characteristics of cereals investigated

Specification	Measure	Average values or name			
Species of cereal	-	wheat	barley	rye	oats
Variety	-	Emika	Aramir I	Dańkowskie	Przebój II
Lenght of stalks	m	0.75-0.79	0.62-0.77	1.09-1.15	≈ 0.64
Lenght of ears	m	0.06-0.08	0.06-0.09	0.05	≈ 0.125
Grain mass-straw mass ratio	-	1:1.08-1:1.12	1:1.15-1:1.24	1:2.0-1:2.1	1:1.54-1:1.63
Straw moisture content:	%				
I date of tests - w_{s1}		12.8-13.6	11.7-12.6	12.8-13.2	11.2-12.1
II date of tests - w_{s2}		17.8-19.2	16.5-17.6	16.8-17.4	15.2-16.4
III date of tests - w_{s3}		22.2-26.2	20.8-26.4	23.2-26.6	20.8-22.4
Grain moisture content	%				
I date of tests - w_{z1}		11.4-13.6	11.3-11.6	10.8-16.6	10.2-10.7
II date of tests - w_{z2}		15.7-17.8	15.0-16.3	15.4-16.4	≈14.6
III date of tests - w_{z3}		17.6-22.1	20.6-23.5	21.2-25.1	18.6-21.3
Macrodamage of grain during control tests:	%				
I date of investigations		0.15	0.09	0.20	0.06
II date of investigations		0.30	0.13	0.35	0.09
III date of investigations		0.51	0.15	0.60	0.10
Microdamage of grain during control tests:	%				
I date of investigations		0.20	0.00	0,25	-
II date of investigations		0.35	0.05	0,50	-
III date of investigations		0.75	0.10	0,75	-

Table 3. Average amount of macrodamage of wheat grain separated by eightdrums and threedrums threshing and separating sets (%)

Capacity (kg/s)				2.5			4.0			5.5			7.0		
								Eightdrums threshing							
Average grain moisture centent (%)				17.6	15.7	13.6	17.6	15.7	13.6	17.6	15.7	13.6	17.6	15.7	13.6
Angular	53	Working	25	4.3	4.3	4.6	2.6	2.7	3.3	2.2	2.3	3.2	1.7	1.7	2.7
speed of		clearence	40	4.1	4.2	4.5	2.4	2.5	3.2	2.1	2.2	3.0	1.5	1.6	2.6
threshing	78	between	25	4.4	4.6	3.1	2.6	2.7	3.6	2.4	2.5	3.5	1.8	1.8	3.1
and separa-		separating	40	4.2	4.3	5.0	2.5	2.6	3.4	2.4	2.5	3.1	1.7	1.7	2.8
ting drums	103	drum and	25	4.5	4.7	5.4	3.1	3.2	4.1	2.4	2.5	4.0	2.1	2.1	3.4
(rad/s)		grid (mm)	40	4.5	4.8	3.2	2.9	3.1	3.9	2.3	2.4	3.8	1.9	2.1	3.3
								Threedrums threshing							
Average grain moisture centent, %				11.4	17.8	22.1	11.4	17.8	22.1	11.4	17.8	22.1	11.4	17.8	22.1
Angular	53	Working	25	2.2	2.3	2.8	2.2	2.3	2.4	2.1	2.0	2.3	1.8	1.6	1.9
speed of		clearence	40	2.1	2.2	2.6	2.0	2.2	2.3	2.0	1.9	2.1	1.7	1.5	1.7
threshing	78	between	25	2.3	2.7	3.0	2.3	2.4	2.4	2.2	2.1	2.4	1.9	1.8	2.0
and separa-		separatng	40	2.1	2.4	2.9	2.1	2.3	2.3	2.1	2.0	2.2	1.8	1.7	1.9
ting drums	103	drum and	25	2.6	2.9	3.2	2.4	2.6	2.7	2.3	2.3	2.4	2.1	2.1	2.1
(rad/s)		grid (mm)	40	2.5	2.6	3.0	2.3	2.6	2.6	2.3	2.2	2.3	2.0	2.1	2.0

Table 4. Average amount of macrodamage of barley, rye and oats grains separated by threedrums threshing and separating sets (%)

Capacity (kg/s)				2.5			4.0			5.5			7.0		
									Barley grain						
Average grain moisture centent (%)				11.6	15.7	23.5	11.6	15.7	23.5	11.6	15.7	23.5	11.6	15.7	23.5
Angular	53	Working	25	2.0	1.9	2.3	2.0	1.8	1.9	1.7	1.5	1.6	1.4	1.3	1.4
speed of		clearence	40	1.8	1.7	2.2	1.9	1.7	1.8	1.7	1.4	1.6	1.4	1.2	1.2
threshing	78	between	25	2.1	2.0	2.4	2.0	1.9	2.1	1.8	1.6	1.8	1.6	1.5	1.5
and separa-		separating	40	1.9	1.8	2.2	1.9	1.9	1.9	1.7	1.5	1.7	1.4	1.2	1.4
ting drums	103	drum and	25	2.3	2.2	2.4	2.3	2.1	2.4	1.9	1.7	2.0	1.7	1.6	1.7
(rad/s)		grid (mm)	40	2.2	2.0	2.3	2.2	2.0	2.3	1.7	1.6	1.9	1.5	1.5	1.6
									Rye grain						
Average grain moisture centent (%)				11.6	16.4	25.1	11.6	16.4	25.1	11.6	16.4	25.1	11.6	16.4	25.1
Angular	53	Working	25	3.5	3.2	3.7	3.0	2.9	3.1	2.5	2.4	2.6	2.2	1.9	2.0
speed of		clearence	40	3.1	3.0	3.4	2.8	2.8	2.9	2.4	2.2	2.4	2.0	1.8	1.9
threshing	78	between	25	3.7	3.3	3.8	3.1	2.9	3.3	2.7	2.5	2.7	2.3	2.0	2.1
and separa-		separating	40	3.3	3.0	3.6	2.8	2.9	3.2	2.5	2.4	2.4	2.1	2.0	2.0
ting drums	103	drum and	25	3.8	3.4	4.1	3.3	3.2	3.6	2.8	2.6	2.9	2.4	2.1	2.2
(rad/s)		grid (mm)	40	3.4	3.1	4.0	3.1	3.1	3.4	2.7	2.2	2.5	2.2	2.1	2.2
									Oats grain						
Average grain moisture centent (%)				10.7	14.8	21.2	10.7	14.8	21.2	10.7	14.8	21.2	10.7	14.8	21.2
Angular	53	Working	25	1.3	1.2	1.2	1.2	1.1	1.3	1.3	1.1	1.0	1.0	0.9	0.8
speed of		clearence	40	1.2	1.0	1.0	2.1	1.0	1.0	1.1	1.0	0.9	09	0.9	0.7
threshing	78	between	25	1.4	1.1	1.5	1.4	1.3	1.3	1.3	1.2	1.3	1.1	1.0	0.9
and separa-		separating	40	1.2	1.1	1.3	1.2	1.1	1.0	1.2	1.0	1.1	1.0	1.0	0.8
ting drums	103	drum and	25	1.7	1.4	1.6	1.5	1.4	1.4	1.5	1.3	1.3	1.2	1.2	1.3
(rad/s)		grid (mm)	40	1.3	1.2	1.4	1.5	1.2	1.2	1.1	1.1	1.2	1.0	1.0	1.1

Table 5. Average amount of microdamage of wheat grain separated by eightdrums and threedrums threshing and separating sets (%)

Capacity (kg/s)				2.5			4.0			5.5			7.0		
				Eightdrums threshing											
Average grain moisture centent (%)				17.6	15.7	13.6	17.6	15.7	13.6	17.6	15.7	13.6	17.6	15.7	13.6
Angular	53	Working	25	6.8	7.2	7.3	6.5	6.6	6.9	6.0	6.3	6.5	5.6	6.0	6.3
speed of		clearence	40	6.4	6.5	7.0	6.2	6.3	6.5	5.7	6.1	6.2	5.3	5.8	6.3
threshing	78	between	25	7.0	7.4	7.9	6.6	7.0	7.2	6.3	6.5	6.9	5.9	6.3	6.6
and separa-		separating	40	6.9	7.2	7.6	6.5	6.7	6.9	6.1	6.3	6.7	5.7	6.2	6.4
ting drums	103	drum and	25	8.7	9.0	9.4	7.6	9.1	8.5	7.2	7.4	7.8	6.7	7.2	7.4
(rad/s)		grid (mm)	40	8.2	8.6	9.0	7.3	7.3	8.1	7.0	7.2	7.4	6.6	6.9	7.1
				Threedrums threshing											
Average grain moisture centent (%)				11.4	17.8	22.1	11.4	17.8	22.1	11.4	17.8	22.1	11.4	17.8	22.1
Angular	53	Working	25	4.0	3.8	4.1	3.6	3.2	3.6	2.6	2.4	2.8	2.4	2.2	2.4
speed of		clearence	40	3.8	3.6	3.8	3.2	3.0	3.4	2.2	2.0	2.2	2.0	1.8	2.2
threshing	78	between	25	4.2	4.0	4.4	3.8	3.4	3.8	3.0	3.0	3.2	2.6	2.4	2.6
and separa-		separating	40	3.8	3.8	4.1	3.2	3.0	3.4	2.8	2.8	3.0	2.4	2.2	2.2
ting drums	103	drum and	25	5.0	4.2	4.8	3.6	3.4	4.0	3.4	3.2	3.6	2.8	2.6	3.2
(rad/s)		grid (mm)	40	4.1	3.8	4.2	3.4	3.2	3.6	3.0	3.0	3.4	2.6	2.4	3.0

separating conditions were at an angular speed of 103 rad/s, a capacity of 2.5 kg/s and a working clearence of 25 mm amounted, respectively:

- for wheat: macrodamage 2.5-4.6 %, microdamage 3.5-8.7 %,
- for rye: macrodamage 2.2-4.1 %, microdamage 3.2-4.9 %.

Oats grain proved to be the most resistant to damage. The amount of damage observed was the least and did not exeed 1.6 %. This resulted from the structure of grain which is covered with a husk protecting it against damage.

It was also stated that the grain of barley was more resistant to damage than the grain of wheat and rye. The amount of microdamage to barley did not exceed 2.2 % whereas in the case of macrodamage was 2.4 %. The least amount of damage to separated grain was observed at the recommended angular speed of separating drums not exeeding 78 rad/s and at grain moisture content of above 20 %.

It should be noted that there is a lack of investigations dealing with damage to grain produced by multidrum threshing and separating sets in the literature available. It was, impossible to compare the results of our investigations with the results obtained by other authors.

CONCLUSIONS

1. The investigation carried out proved that all of the factors analysed determined the amount of damage in the separated grain.

2. The amount of grain damage was most influenced by the number of working sections of the separating set. The grain separated by the eightdrum separator was therefore characterized by about twice as much damage as the grain separated by the threedrums separators.

3. The grain was characterized by different amount of mechanical damage according to cereal variety. The grain of barley and oats proved to be the most resistant to damage. The grain of rye and wheat showed the least resistance.

4. The least amount of grain damage was observed at a separating drum speed not exceeding 78 rad/s (15 m/s).

5. Increase in working clearence and in capacity of multidrums separators results in a decrease in the amount of mechanical damage to separated grain.

Table 6. Average amount of microdamage of barley and rye grains separated by threedrums threshing and separating sets (%)

Capacity (kg/s)				2.5			4.0			5.5			7.0		
							Barley grain								
Average grain moisture centent (%)				11.6	15.7	23.5	11.6	15.7	23.5	11.6	15.7	23.5	11.6	15.7	23.5
Angular	53	Working	25	1.2	1.2	1.6	1.4	1.2	1.4	1.6	1.2	1.4	1.2	1.2	1.4
speed of		clearence	40	1.0	1.0	1.2	1.0	1.2	1.2	1.2	1.0	1.2	1.0	1.0	1.0
threshing	78	between	25	1.6	1.4	1.8	1.6	1.4	1.6	1.6	1.4	1.4	1.2	1.4	1.4
and separa-		separating	40	1.2	1.2	1.4	1.4	1.2	1.4	1.4	1.0	1.2	1.0	1.4	1.2
ting drums	103	drum and	25	2.0	1.8	2.2	2.0	1.6	2.0	1.6	1.6	1.8	1.4	1.6	1.6
(rad/s)		grid (mm)	40	1.8	1.6	2.0	1.6	1.2	1.4	1.4	1.2	1.6	1.4	1.2	1.4
							Rye grain								
Average grain moisture centent (%)				11.6	16.4	25.1	11.6	16.4	25.1	11.6	16.4	25.1	11.6	16.4	25.1
Angular	53	Working	25	3.8	3.2	4.0	3.6	3.2	3.6	3.2	3.0	3.4	2.8	2.6	2.6
speed of		clearence	40	3.2	3.0	3.8	3.2	3.0	3.4	2.8	2.6	3.0	2.8	2.2	2.4
threshing	78	between	25	3.8	3.6	4.2	3.4	3.2	3.8	3.2	3.2	3.4	3.0	2.8	2.8
and separa-		separating	40	3.0	3.2	4.0	3.2	2.8	3.4	3.0	2.6	3.0	2.8	2.2	2.2
ting drums	103	drum and	25	4.8	4.2	4.9	4.2	3.8	4.1	3.6	3.4	3.8	3.2	3.1	3.3
(rad/s)		grid (mm)	40	4.4	4.0	4.4	4.0	3.4	3.6	3.2	3.0	3.6	3.0	2.8	3.0

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