

# TEKA

*PÓŁROCZNIKIEM JOURNAL OF AGRI-FOOD INDUSTRY*

*Vol. 21, No 1*

*RZESZOW- LVIV 2021*

#### *Editor-in-Chief*

*Eugeniusz KRASOWSKI, Polish Academy of Sciences in Lublin, Poland*

#### *Deputy Editor-in-Chief*

*Stepan KOVALYSHYN, Lviv National Agrarian University in Dublany, Ukraine*

*Ivan ROGOVSKII, National University of Life and Environmental Sciences in Kiev, Ukraine*

*Stanisław SOSNOWSKI, University of Engineering and Economics in Rzeszow, Poland*

#### *Assistant Editor*

*Piotr KUŹNIAR, University of Rzeszow, Poland*

*Vadym PTASHNYK, Lviv National Agrarian University in Dublany, Ukraine*

#### *Editorial Board*

*Viacheslav ADAMCHUK, McGill University, Canada*

*Maciej BILEK, University of Rzeszow, Poland*

*Miroslav PRÍSTAVKA, Slovak University of Agriculture in Nitra, Slovak Republic*

*Lidia GAIGINSCHI, Technical University of Iasi "Gheorge Asachi", Romania*

*Andriy CHABAN, Lviv National Agrarian University, Ukraine*

*Pavol FINDURA, Slovak University of Agriculture in Nitra, Slovak Republic*

*Józef GORZELANY, University of Rzeszow, Poland*

*Mukrimin GUNEY, Giresun University, Turkey*

*Rebecca HARBUT, Kwantlen Polytechnic University, Canada*

*Kui JIAO, Qingdao University of Science and Technology, China*

*Plamen KANGALOV, University of Ruse "Angel Kanchev", Bulgaria*

*Kamil KAYGUSUZ, Karadeniz Technical University, Turkey*

*Sergiy KHARCHENKO, Kharkiv Petro Vasylenko National Technical University of Agriculture, Ukraine*

*Józef KOWALCZUK, University of Life Sciences in Lublin, Poland*

*Roman KUZMINSKY, Lviv National Agrarian University in Dublany, Ukraine*

*Jean-Pierre LEMIERE, Agrosup Dijon, France*

*Kazimierz LEJDA, Rzeszów University of Technology, Poland*

*Jan MARECEK, Mendel University in Brno, Czech Republic*

*Till MEINEL, Koln University of Technology, Art and Sciences, Germany*

*Viktor MELNYK, Kharkiv Petro Vasylenko National Technical University of Agriculture, Ukraine*

*Stepan MYAGKOTA, Lviv National Agrarian University in Dublany, Ukraine*

*Jan OSZMIAŃSKI, Wrocław University of Environmental and Life Sciences, Poland*

*Richard ROUSH, Pennsylvania State University, USA*

*Povilas A. SIRVYDAS, Agrarian University in Kaunas, Lithuania*

*Jan TURAN, University of Novi Sad, Serbia*

*Andrzej TOMPOROWSKI, University of Sciences and Technology in Bydgoszcz, Poland*

*Dainis VIESTURS, Latvia University of Agriculture, Latvia*

*Ali Al-ZUBIEDY, University of Babylon, Iraq*

**Linguistic consultant:** *Natalya Havryshkiv*

**Typeset:** *Serhii Korobka*

**Cover design:** *Serhii Korobka*

*All the articles are available on the webpage:  
<http://tekajournal.pl/index.php/TEKA>*

*All the scientific articles received positive evaluations by independent reviewers*

*ISSN 2657-9537*

*© Copyright by University of Engineering and Economics in Rzeszów 2021  
in co-operation with Lviv National Agrarian University 2021*

**Editorial Office address**

*University of Engineering and Economics in Rzeszów  
Miłocińska 40, 35-232 Rzeszów, Poland  
e-mail: [teka@wsie.edu.pl](mailto:teka@wsie.edu.pl)*

**Publishing Office address**

*University of Engineering and Economics in Rzeszów  
Miłocińska 40, 35-232 Rzeszów, Poland  
e-mail: [teka@wsie.edu.pl](mailto:teka@wsie.edu.pl)*

**Printing**

*Publishing House „**SPOLOM**“  
St. Krakivska, 9, Lviv, 79000*

*Edition 150+21 vol.1*

## INVESTIGATION OF DIMENSIONAL CHARACTERISTICS OF PEA AND MILLET GRAIN

*Nanka O.V., Candidate of Science (Engineering), Prof., Academician of INAS, Bakum M.V., Ph.D., Prof., Nagaev V.M., Ph.D., Prof., Krekot M.M., Ph.D., Assoc., Sementsov V.V., Ph.D., Assoc., Mityashkina T.Yu., Ph.D., Assoc., Shchur T.G., Ph.D., Assoc.*

*Lviv National Agrarian University  
Ukraine, Dublyany, V. Velykoho str., 1.  
e-mail: shchurtg@gmail.com*

**Abstract.** Crop yields have been significantly affected by arid weather over the past five years. They lead not only to a decrease in crop yields, but also to a decrease in the quality of the crop grown. First of all, its grain part includes a considerable amount of soft underdeveloped grain with a total weight reduction of 1000 seeds of the main crop.

Post-harvest treatment of the grain part of such a crop is associated with the separation of part of the grain of the main crop into waste fractions. The content of these fractions, after appropriate refinement, can be a valuable component of the feed and feed additives required for the complete feeding of farm animals. To obtain balanced and nutritional nutritious feeds, it is necessary to have finely ground with small particle sizes of all components and their particle size distribution.

The process of grinding by rotary shredder is promising. To substantiate the parameters of such shredders and to choose the modes of their operation requires a thorough study of the mechanical and technological properties of all components of the original grain materials, including their size and shape. The variability of grain sizes was estimated by its geometric dimensions: thickness, width and length, their statistical characteristics and equivalent diameter. The sampling volume of each grain was 100 units for reliable results. Separate whole grains of peas and millet and the characteristic halves of peas were studied.

Studies of the dimensional characteristics of the grain of the pea of the Motto variety, its halves and the grain of millet Slobozhanske found that their average values of length, width and thickness differ

significantly and the standard deviation of their thickness 1.33 mm, width - 1.47 mm, and lengths - 1, 51 mm. The coefficient of variation of the length of the studied grain is 34.40%, width - 39.73%, and thickness - 47.33%. The average equivalent diameter of the studied grain varies from 2.52 mm grains of Slobozhanske millet to 7.20 mm grains of Motto pea. The smallest weight of 1000 pieces also has millet grain - 7.54 g, and the largest - pea grain - 258.77 g.

**Keywords.** Variability of grain size characteristics, width, thickness, length, peas, millet, halves of peas, average equivalent diameter, shape.

**Formulation of the problem.** An important component of increasing both the livestock population and improving their productivity is the formation of a stable forage based on priority feeds based on updated performance criteria (Hnoyevyy *et al.* 2018).

The crop yields of the last five years have been significantly influenced by weather conditions (Kumhalova *et al.* 2008). Thus, the average daily air temperature in the forest-steppe and steppe zones of Ukraine exceeds long-term indicators, and a small amount of rainfall in the autumn-winter period, prolonged droughts and rainfall in the spring-summer period leads to a lack of productive moisture in the soil. Also, there is a significant increase in the likelihood of hot periods, with temperatures higher than 30 ° C, during the growing season of crops.

All this leads not only to a decrease in crop yields, but also to a decrease in the quality of the cultivated crop. First of all, its grain part includes a considerable amount of soft underdeveloped grain with a total weight reduction of 1000 seeds of the main crop. In

addition, the drying of inflorescences, spikelets, beans of plants leads to an increase in their crushed particles, with the dried seeds of the main crop, in the grain part of the crop. In this case, the grains of the main crop become less resistant to the mechanical impact of the working organs of both harvesting machines and equipment for post-harvest processing of the crop, which increases not only their injury, but also partial grinding, or splitting into halves, for example, pea grains.

Post-harvest treatment of the grain part of such a crop, bringing the target fraction to the requirements of state standards for food grain, and even more so for the sowing material, associated with the separation of part of the grain of the main crop to waste fractions. The content of these fractions, after appropriate refinement, can be a valuable component of the feed and feed additives required for the complete feeding of farm animals (Provatorov *et al.* 2007). So, for example, defective crushed pea grains contain from 16 to 36% protein, up to 48% starch, up to 10% sugar, up to 1.6% fat, over 3% ash, and millet starch is more than 80% weight, protein - 12%, and fat - 3,5%. In addition, they include mineral salts of potassium, calcium, sodium, magnesium, as well as vitamins (Khorasani *et al.* 2007; Bingol *et al.* 2008; Wadhwa *et al.* 2007).

To obtain balanced and nutritional nutritious feeds, it is necessary to have finely ground with small particle sizes of all components and their particle size distribution (Wadhwa *et al.* 2007).

Crushing grain with a blow does not fully meet the requirements (Revenko *et al.* 2009; Syrotyuk *et al.* 2004). More promising is the process of grinding by rotary shredders (Nanka *et al.* 2018; Naumenko *et al.* 2019),

but to substantiate the parameters of such shredders and the choice of modes of their operation requires a thorough study of the mechanical and technological properties of all components of the original grain materials for grinding, including their size and shape (Tsarenko *et al.* 2003).

**The purpose of the work.** Investigate the variability of grain size of peas and millet, which is separated into the waste fraction when preparing the conditioned seed.

**Research results.** Grain mixtures of the motto of the Motto variety and the Slobozhanskemillet were investigated, which were separated into the waste fractions during the preparation of the seed material on the grain processing lines.

The variability of grain sizes was estimated by its geometric dimensions: thickness, width and length, their statistical characteristics and equivalent diameter. The sampling volume of each grain, for reliable results (Tsarenko *et al.* 2003), was taken by 100 pieces. Separate whole grains of peas and millet and the characteristic halves of peas were studied.

The dimensions of each grain were measured separately with a microscope with an accuracy of 0.01 mm. The results of measurements of grain sizes, in the form of variation rows, are given in Tables 1...3 and the variation curves in Fig. 1.

Whole grain pea has the greatest dispersion of thickness (Table 1, Fig. 1a), and the least - millet grain. The thickness of whole grain peas varies from 1.89 mm to 6.45 mm, and its halves from 1.44 to 3.79 mm. The scattering thickness of the Slobozhanske millet grain varies only from 1.75 to 2.31 mm.

**Table 1.** Variation series of grain thickness

| Interval limits, mm | 1,0-1,5                             | 1,5-2,0 | 2,0-2,5 | 2,5-3,0 | 3,0-3,5 | 3,5-4,0 | 4,0-4,5 | 4,5-5,0 | 5,0-5,5 | 5,5-6,0 | 6,0-6,5 |
|---------------------|-------------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Frequency, %        | The pea of "Motto" variety          |         |         |         |         |         |         |         |         |         |         |
|                     |                                     |         | 4       | 5       | 9       | 23      | 15      | 15      | 12      | 11      | 5       |
| Frequency, %        | The half of peas of "Motto" variety |         |         |         |         |         |         |         |         |         |         |
|                     | 4                                   | 44      | 36      | 10      | 4       | 2       |         |         |         |         |         |
| Frequency, %        | Millet of Slobozhanske variety      |         |         |         |         |         |         |         |         |         |         |
|                     | 2                                   | 61      | 37      |         |         |         |         |         |         |         |         |

Millet grain also has the lowest average thickness. It is 1.98 mm. The average width of the pea halves is more than 0.13 mm of the average thickness of the millet. The largest value of the average value of the

thickness of a whole pea. It is 2.20 times larger than average thickness of millet grain, 2.06 times larger than average thickness of half peas and is 4.35 mm.

**Table 2.** Variation rows of grain width

| Interval limits, mm | 1,5-2,0                             | 2,0-2,5 | 2,5-3,0 | 3,0-3,5 | 3,5-4,0 | 4,0-4,5 | 4,5-5,0 | 5,0-5,5 | 5,5-6,0 | 6,0-6,5 | 6,5-7,0 | 7,0-7,5 | 7,5-8,0 |
|---------------------|-------------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Frequency, %        | The pea of "Motto" variety          |         |         |         |         |         |         |         |         |         |         |         |         |
|                     |                                     |         |         | 5       | 7       | 15      | 19      | 15      | 14      | 11      | 9       | 4       | 2       |
| Frequency, %        | The half of peas of "Motto" variety |         |         |         |         |         |         |         |         |         |         |         |         |
|                     |                                     | 6       | 12      | 37      | 31      | 12      | 2       |         |         |         |         |         |         |
| Frequency, %        | Millet of Slobozhanske variety      |         |         |         |         |         |         |         |         |         |         |         |         |
|                     | 1                                   | 73      | 26      |         |         |         |         |         |         |         |         |         |         |

By the size of scattering, the width of the peas grains of the motto of the motto is much greater than the scattering of the width of its halves, and even more so - the grains of millet Slobozhanske. Thus, the width of

the pea grains varies from 3.20 to 7.63 mm, and the width of the millet grains - only from 1.86 to 2.69 mm (Table 2, Fig. 1b).

**Table 3.** Variation series of grain length.

| Interval limits, mm | 2,5-3,0                             | 3,0-3,5 | 3,5-4,0 | 4,0-4,5 | 4,5-5,0 | 5,0-5,5 | 5,5-6,0 | 6,0-6,5 | 6,5-7,0 | 7,0-7,5 | 7,5-8,0 | 8,0-8,5 |
|---------------------|-------------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Frequency, %        | The pea of "Motto" variety          |         |         |         |         |         |         |         |         |         |         |         |
|                     |                                     |         |         | 4       | 7       | 18      | 20      | 22      | 13      | 8       | 4       | 4       |
| Frequency, %        | The half of peas of "Motto" variety |         |         |         |         |         |         |         |         |         |         |         |
|                     |                                     | 15      | 41      | 34      | 10      |         |         |         |         |         |         |         |
| Frequency, %        | Millet of Slobozhanske variety      |         |         |         |         |         |         |         |         |         |         |         |
|                     | 18                                  | 80      | 2       |         |         |         |         |         |         |         |         |         |

The average values of the width of the studied grain also differ significantly. The largest average value is the width of pea grains (5.29 mm) and the smallest - 2.38 mm width of millet grains (Table 4). The average width of the pea halves is less than the average of the whole grain by only 1.54 times.

The average value of the width of the test grain is 3.70 mm, which is 0.89 mm more than the average value of its thickness. In general, the pattern of variability in the width of the test grain is almost indistinguishable from the variability of its thickness. By absolute values of the mean values, the largest difference in width and thickness are half the pea grains. It is 1.33 mm. Whole pea grains have a difference of 0.94 mm, while millet grains have a difference of only 0.4 mm. The scattering of the length of whole

grains of peas of the motto of the motto significantly exceeds the scattering of the length of its halves and grains of millet Slobozhanske. Thus, the scattering of the length of pea grains varies from 4.13 to 8.14 mm, its halves - from 3.04 to 4.78 mm, and millet grains - from 2.72 to 3.49 mm (Table 3.4, Fig. 1, c).

The average length of whole grains of peas is also the largest and is 6.07 mm. Halves average less than 1.54 times the length of a whole pea, but 1.11 times longer than the length of a millet grain. The slight difference in the mean values of the thickness, width and length of the test grain indicates the similarity of its spherical shape.

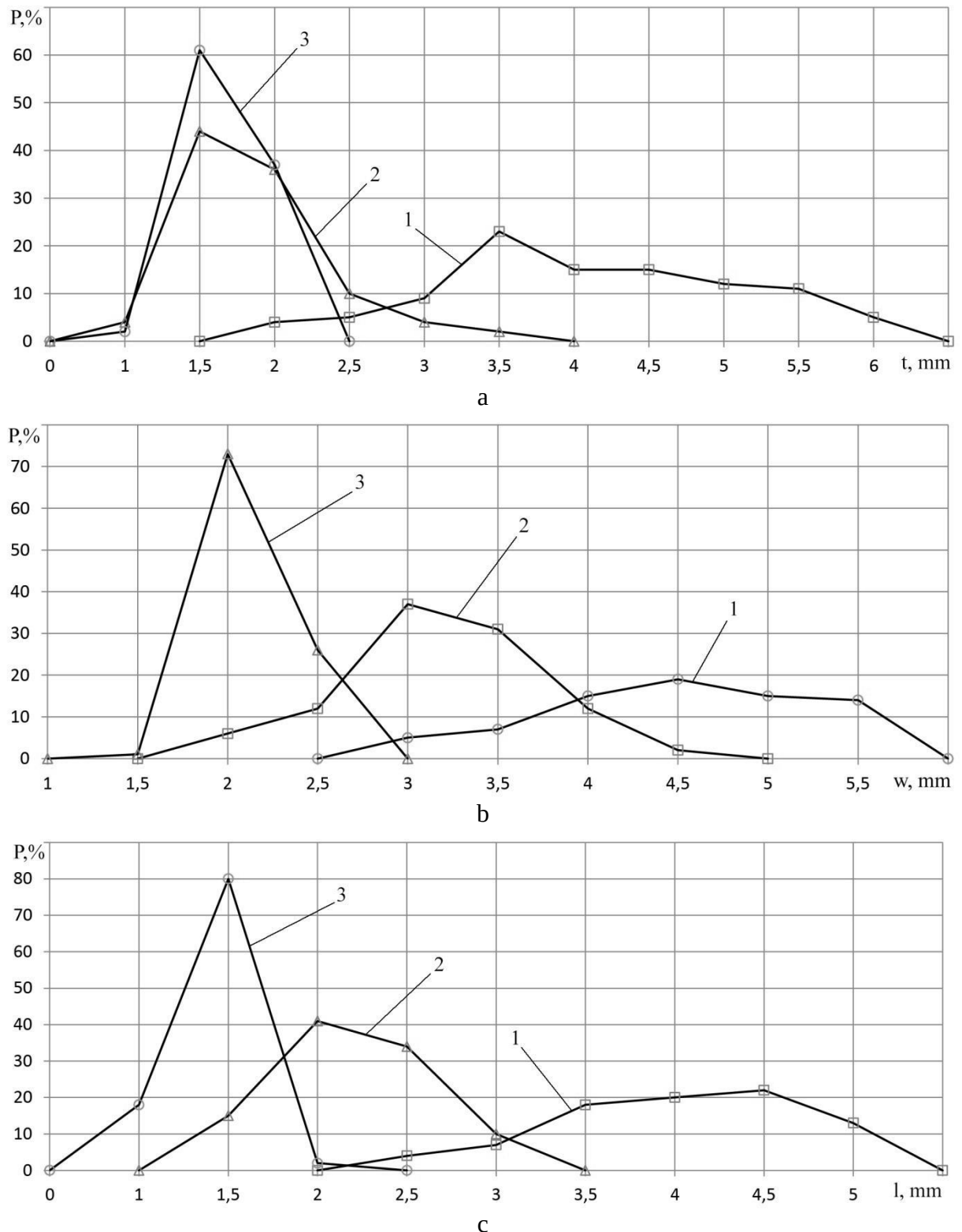
The average value of the length of the test grain is 4.39 mm and only 0.69 mm more than the average width value, and 1.58 mm average value of its thickness. On the whole,

the smallest dispersion of all sizes has millet grain, and the largest - whole pea grain. It should be noted that the size of peas is much larger than millet grains. Thus, the average thickness of pea grains is 2.20 times greater than the average thickness of millet grains, the average width is greater by 2.22 times, and the average length is greater by 1.93 times the average length of millet grains. The average size of a whole pea is also much larger than the corresponding size of its halves. Therefore, the standard deviations of

the average sizes of the studied grain are significant in magnitude and vary from 1.33 mm for grain thickness, 1.47 mm for width and 1.51 mm for length. This determines the variation of the coefficients of variation of the average size of the studied grain from 34.40% for length, 39.73% for width and up to 47.33% for thickness (Table 4), which must be taken into account when adjusting the shredders to obtain homogeneous composition of all feed components.

**Table 4.** Statistical indicators of variability of grain sizes

| Agrarian culture<br>Indicators           | The pea of "Motto" variety | The half of peas of "Motto" variety | Millet of Slobozhansk e variety | The average value of the dimensions, mm | The standard deviation of the dimensions, mm | Coefficient of variation of sizes, % |
|------------------------------------------|----------------------------|-------------------------------------|---------------------------------|-----------------------------------------|----------------------------------------------|--------------------------------------|
| Minimum grain thickness, mm              | 1,89                       | 1,94                                | 1,75                            |                                         |                                              |                                      |
| Maximum grain thickness, mm              | 6,45                       | 3,79                                | 2,31                            |                                         |                                              |                                      |
| The average value of grain thickness, mm | 4,35                       | 2,11                                | 1,98                            | 2,81                                    | 1,33                                         | 47,33                                |
| Minimum grain width, mm                  | 3,20                       | 2,21                                | 1,86                            |                                         |                                              |                                      |
| Maximum grain width, mm                  | 7,63                       | 4,78                                | 2,69                            |                                         |                                              |                                      |
| Average value of grain width, mm         | 5,29                       | 3,44                                | 2,38                            | 3,70                                    | 1,47                                         | 39,73                                |
| Minimum grain length, mm                 | 4,13                       | 3,04                                | 2,72                            |                                         |                                              |                                      |
| Maximum grain length, mm                 | 8,14                       | 4,78                                | 3,49                            |                                         |                                              |                                      |
| The average value of grain length, mm    | 6,07                       | 3,95                                | 3,15                            | 4,39                                    | 1,51                                         | 34,40                                |



**Figure 1.** Variation curves of grain size characteristics: a - thickness, b - width, c - length; 1 - peas of the motto of the motto; 2 - half of peas of the motto of the motto; 3 - Slobozhanske millet.

To estimate the variety of forms of pea grains, their halves and millet grains when grinding them into animal feed, as for other agricultural crops, we take the equivalent grain size as the diameter of a ball whose

volume is equal to the actual grain volume (Tsarenko *et al.* 2003).

To ensure the accuracy of the grain volume, we first determine the quantity of grain and its total volume in a 100 ml flask



(Tsarenko *et al.* 2003). To this end, the grain filled flask was supplemented with water from the measuring beaker, determining its volume. The difference between the volume of the flask and the refilled water is the total volume of grain in the flask. By dividing it by

the amount of grain in the flask, we determined the average volume of one grain. By equating it to the volume of a ball, the average equivalent diameter of the test grain was determined (Tsarenko *et al.* 2003). The results are shown in table. 5.

**Table 5.** Average equivalent diameter of the test grain

| Grain variety<br>Indicators                 | The pea of<br>"Motto" variety | The half of peas<br>of "Motto"<br>variety | Millet of<br>Slobozhanske<br>variety | Average value |
|---------------------------------------------|-------------------------------|-------------------------------------------|--------------------------------------|---------------|
| Average volume<br>of grain, mm <sup>3</sup> | 195,52                        | 92,96                                     | 8,39                                 | 98,96         |
| Average<br>equivalent<br>diameter, mm       | 7,20                          | 5,62                                      | 2,52                                 | 5,11          |
| Weight of 1000<br>grains, g                 | 258,77                        | 127,32                                    | 7,54                                 | 131,21        |

A significant excess of the size of a pea grain determines a significant excess of its average volume, average equivalent diameter and weight of 1000 grains of the corresponding indicators of both half peas and millet grains. Thus, the average volume of whole grain peas of the Motto variety is 195.52 mm<sup>3</sup>, its halves - 92.96 mm<sup>3</sup>, and the grain of Slobozhanske millet - only 8.39 mm<sup>3</sup>. The average volume of such grains is 98.96 mm<sup>3</sup>.

Based on the average volume obtained, we determined the value of the equivalent grain diameter as the diameter of the sphere of the resulting volume. The largest average equivalent diameter of the grain has a pea of the motto of the motto - 7.20 mm, the diameter of its halves is 5.62 mm, and the smallest diameter of the grains of the millet Slobozhanske- only 2.52 mm. In this case, the average value of equivalent diameters of the studied grains is 5.11 mm.

By weight of 1000 seeds the grains of the motto pea variety - 258.77 g, its halves are more than twice as heavy, and the weight of 1000 grains of Slobozhanske millet is only 7.54 g. 131,21 g, which must also be taken into account when adjusting the shredders to obtain homogeneous components of feed mixtures.

## CONCLUSIONS

Investigations of the dimensional characteristics of the pea grain Motto, its halves and grain millet Slobozhanske, which are separated in the waste fraction in the preparation of conditioned seed on grain-cleaning units from seed mixtures grown in arid conditions under shortage the average values of length, width and thickness differ significantly and the standard deviation of their thickness is 1.33 mm, width - 1.47 mm, and length - 1.51 mm. The coefficient of variation of the length of the studied grain is 34.40%, width - 39.73%, and thickness - 47.33%.

The average equivalent diameter of the studied grain varies from 2.52 mm grains of Slobozhanske millet to 7.20 mm grains of Motto pea.

The smallest weight of 1000 pieces also has millet grain - 7.54 g, and the largest - pea grain - 258.77 g.

## REFERENCES

- Hnoyevyy V. I., Lebedyns'kyi V. I. 2018. Dobrobutko rivnamolochnykh fermakh : «Operatyvn apolihrifiya» FOP Zdorovyy Y A. A., 248 s (in Ukraine).  
Kumhalova J., Kumhala F., Kroulik M., Matejkova S. Muasya R. M., Lommen W. J. M., Muui C. W., Struik P. C. 2008. How weather during

- development of common bean (*Phaseolus vulgaris* L.) affects the crop's maximum attainable seed quality. *Njas-wageningen journal of life sciences*. Vol. 56. № 1-2. P. 85-100. DOI10.1016/S1573-5214(08)80018-8 (in Ukraine).
- Normy hodivli, ratsiony i pozhyvnist' kormiv dlya riznykh vydiv sil's'kohospodars'k ykhtvaryn: [dovidky]. Provatorov S. V., Ladyka V. I., Bondarchuk L. V. Sumy: TOV VTD Universytet s'kaknyha, 2007. 488 s (in Ukraine).
- Soto-Navarro S. A., Encinias A. M., Bauer M. L., Lardy G. P., Caton J. S. 2012. Feeding value of field peas as a protein source in forage-based diets for beef cattle. *Journal of animal science*. Vol. 90. № 2. P. 585-591. DOI10.2527/jas.2011-4098 (in Ukraine).
- Khorasani G. R., Okine E. K., Corbett R. R., Kennelly J. J. 2001. Nutritive value of peas for lactating dairy cattle. *Canadian journal of animal science*. Vol. 81. № 4. P. 541-551. DOI 10.4141/A01-019 (in Ukraine).
- Nutritional evaluation of grain and straw fraction of pea genotypes grown under arid conditions. Bingol N. T., Bolat D., Levendoglu T., Togay Y., Togay N. *Journal of applied animal research*. 2008. Vol. 33. № 1. P. 93-97. DOI 10.1080/09712119.2008.9706905 (in Ukraine).
- Wadhwa M. D., Paul P., Kataria M. P. S., Bakshi E. P. 1998. Effect of particle size of corn grain on the rate of nutrient absorption and digestibility. *Animal feed science and technology*. Vol. 72. № 1-2. P. 11-17. DOI 10.1016/S0377-8401(97)00185-5 (in Ukraine).
- Revenko I. I., Revenko I. I., Brahinet's' M. V., Ryabenkotain V. I. Mashynyt aobladn an nyadlyatva rynnnytstva. K.: Kondor, 2009. 730 s (in Ukraine).
- Syrotyuk V. M. Mashyny ta obladnannnyadly atvarynnytstva. L'viv: Mahnoliyaplyus, 2004. 204 s.
- Patent Ukrayiny № 95760, MPK V02S18/04. Sposib podriblennya furazhnoho zerna. Nanka O. V. Opubl. 12.01.2015, Byul. №1. 3 s (in Ukraine).
- Nanka O. V. Doslidzhennya mekhaniko-tekhnologichnykh vlastyvostey zernasoyi. Mekhanizatsiya sil's'koho spodars'koho vyrobnytstva: visnyk KHNTUS-H, Vyp. 190. Kharkiv, 2018. S. 130-138 (in Ukraine).
- Patent Ukrayiny № 131348, MPK V02S9/02. Frezernyy podribnyuvach zerna / Nanka O. V., Naumenko O. A., Bakum M. V. Opubl. 10.01.2019, Byul. № 1. 6 s (in Ukraine).
- Nanka O., Boyko I. 2013. Analytical researches of methods and construction of grinders of corn forage. *Motrol. Commission of Motorization and Energetics in Agriculture*. Lublin, Vol. 15. № 7. P. 5-9 (in Poland).
- Mekhaniko-tekhnologichni vlastyvostisil s'kohospodars'kykh materialiv: Pidruchnyk/ Tsarenko O. M., Voytyuk D. H., Shvayko V. M., Dovzhyk M. Y. A., Yatsun S. S.; za red. S. S. Yatsuna. K.: Meta, 2003. 448 s (in Ukraine).



## THE OUTER TEMPERATURE EFFECT ON THE OF LED LAMPS WORKING CHARACTERISTICS

Markian Goshko

Lviv National Agrarian University  
Ukraine, Dublyany, V. Velykoho str., 1.  
e-mail: [m121314@ukr.net](mailto:m121314@ukr.net)

**Abstract.** Electricity production in the state in 2017 decreased by 10.2% compared to the previous year to 163.3 billion kWh. At the same time, the saving of electric energy is of interest not only to the state and business owners, but also to the representatives of ordinary households.

Every year the issue of energy saving and energy efficiency is becoming more and more relevant. There are a number of reasons for this, among which one can distinguish:

- shortage of energy resources in Ukraine;
- reduction of natural resources;
- rising prices for energy imports;
- annual increase in electricity consumption.

Nuclear power plants, which today produce almost 60%, in 2017 reduced electricity production by 0.9% compared to the previous year to 87.6 billion kilowatt-hours.

So the problem of energy conservation has a global scale. Up to 20% of the total electricity consumption in the industry falls on electric lighting. One of the ways to increase energy efficiency is to modernize the lighting.

A few years ago, the introduction of LED-type lamps was too expensive, so it's not effective. Therefore, we decided to experiment experimentally with the introduction of different types of lamps, and to compare their economic expediency in time. But the situation in the market is changing, the cost of LEDs is reduced, as well as the electricity consumption.

**Keywords:** LED lamps, energy saving lamps, LED lamps composition.

### THE FORMULATION OF THE PROBLEM

The problem of energy conservation has a global scale. Up to 20% of the total electricity consumption in the industry falls on electric lighting. One of the ways to increase energy efficiency is to modernize the lighting.

Our experiments indicate that many LEDs are poorly-matched, but not always consistent with the characteristics of manufacturers.

Also, at the moment, the issue of the influence of ambient temperature on the operation of LED lamps and their lighting characteristics has not been sufficiently studied.

### ANALYSIS OF THE LAST RESEARCHES AND PUBLICATIONS

Having analyzed the available modern light sources, the main generalized characteristics of light sources.

After analyzing the above information and taking into account the problems of energy saving, it can be argued that one of the effective ways to reduce consumption (EC) for lighting is the replacement of incandescent lamps (IL) for compact fluorescent lamps (CFLs), whose light output is 4-5 times higher than in LR (Goshko, 2014; Goshko *et al.* 2015a; Goshko *et al.* 2015b), and light-emitting diode (LED) lamps with light output of 5-8 times higher than LR, both in the illumination of the production complex, (Goshko, 2015; Goshko, 2016; Goshko *et al.* 2016) and in the housing and communal services. Street lighting is considered more economically - advantageous when using

sodium lamps of high pressure with light output of 100 - 130 lm/W. (Hoshko, 2017)

### FORMULATION OF THE PROBLEM

The purpose of the study is to investigate the effect of ambient temperature on the operation of LED lamps and their lighting characteristics.

### MAIN MATERIAL

When choosing LED lamps before we bought them, we were only observing one parameter, all LEDs should have only one power, and for a more illustrative example,

they would purchase for their experiments about 10 pieces in a different price category.

Actually all parameters were respected. The largest selection of available bulbs for the E-27 cartridge was 10-inch representatives of all existing brands.

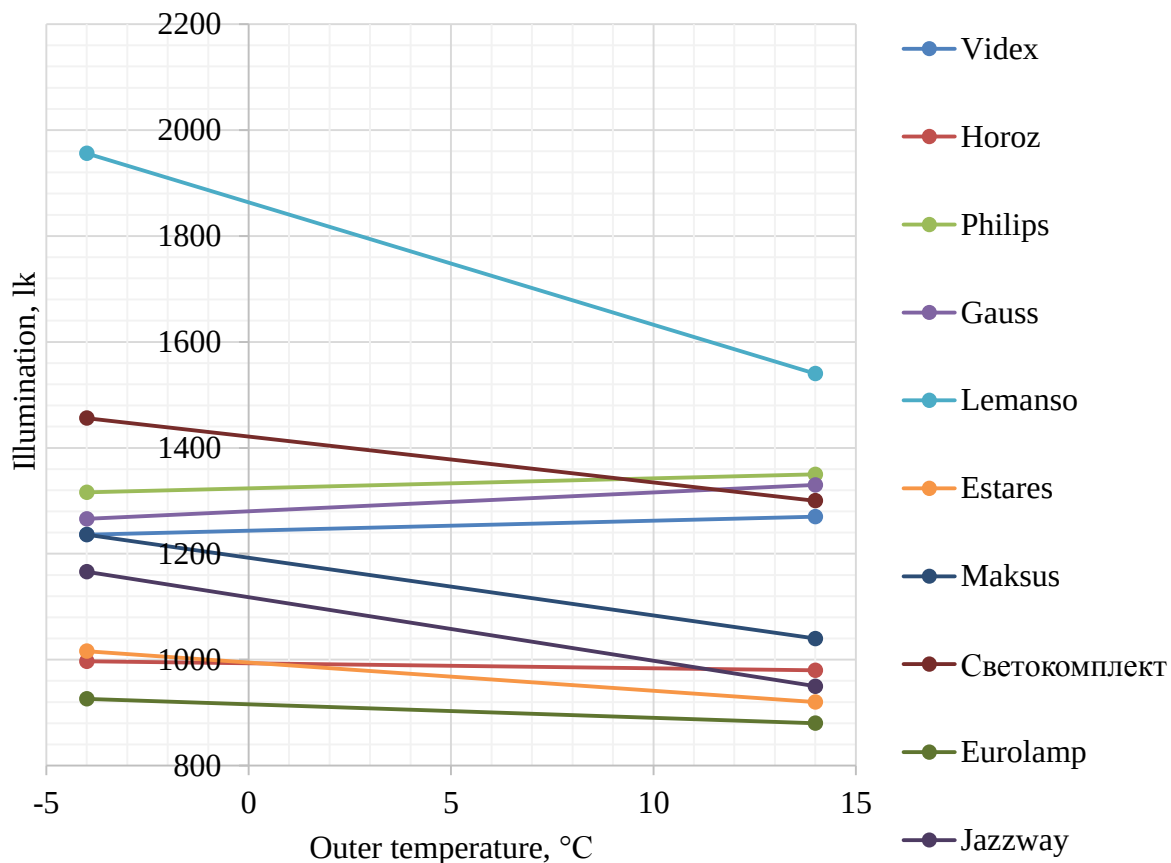
After completing the research one of the representatives of our lamps formed dependencies of various parameters to better compare them amongst themselves.

Their list, specifications and price are given in Table 1.

An experiment was conducted to change the lighting, depending on the ambient temperature. The data is included in the graph in figure 1.

**Table 1** Characteristics of lamps, specified by manufacturers

| Title            | Voltage, V | P, Bt | Light flux | Guarantee           | Manufacturing Country | Price     |
|------------------|------------|-------|------------|---------------------|-----------------------|-----------|
| Светокомплект    | 165-265    | 10    | 840        | 3 years (30 000hr.) | China                 | 56.88 hrn |
| EUROLAMP         | 175-250    | 10    | 1000       | 10 years (50 000)hr | Germany               | 59.88 hrn |
| PHILIPS          | 220-240    | 10    | 900        | 3 years (20 000hr.) | China                 | 53.94 hrn |
| Expert10 (Horoz) | 220-240    | 10    | 900        | 2 years (25 000hr.) | China                 | 72 hrn    |
| Lemanso          | 175-265    | 10    | 1020       | 2 years -           | China                 | 45 hrn    |
| Estares          | 175-265    | 10    | 820        | 2 years (30 000hr.) | China                 | 54.96hrn  |
| Videx            | 175-250    | 10    | 900        |                     |                       |           |
| Maxus            | 175-250    | 10    | 950        | 2 years (40 000hr.) | China                 | 50 hrn    |
| Gauss            | 150-265    | 10    | 920        | 3 years (30 000hr.) | China                 | 61.98hrn  |
| Jazzway          | 230        | 10    | 800        | 3 years (35 000hr.) | China                 | 64.92 hrn |



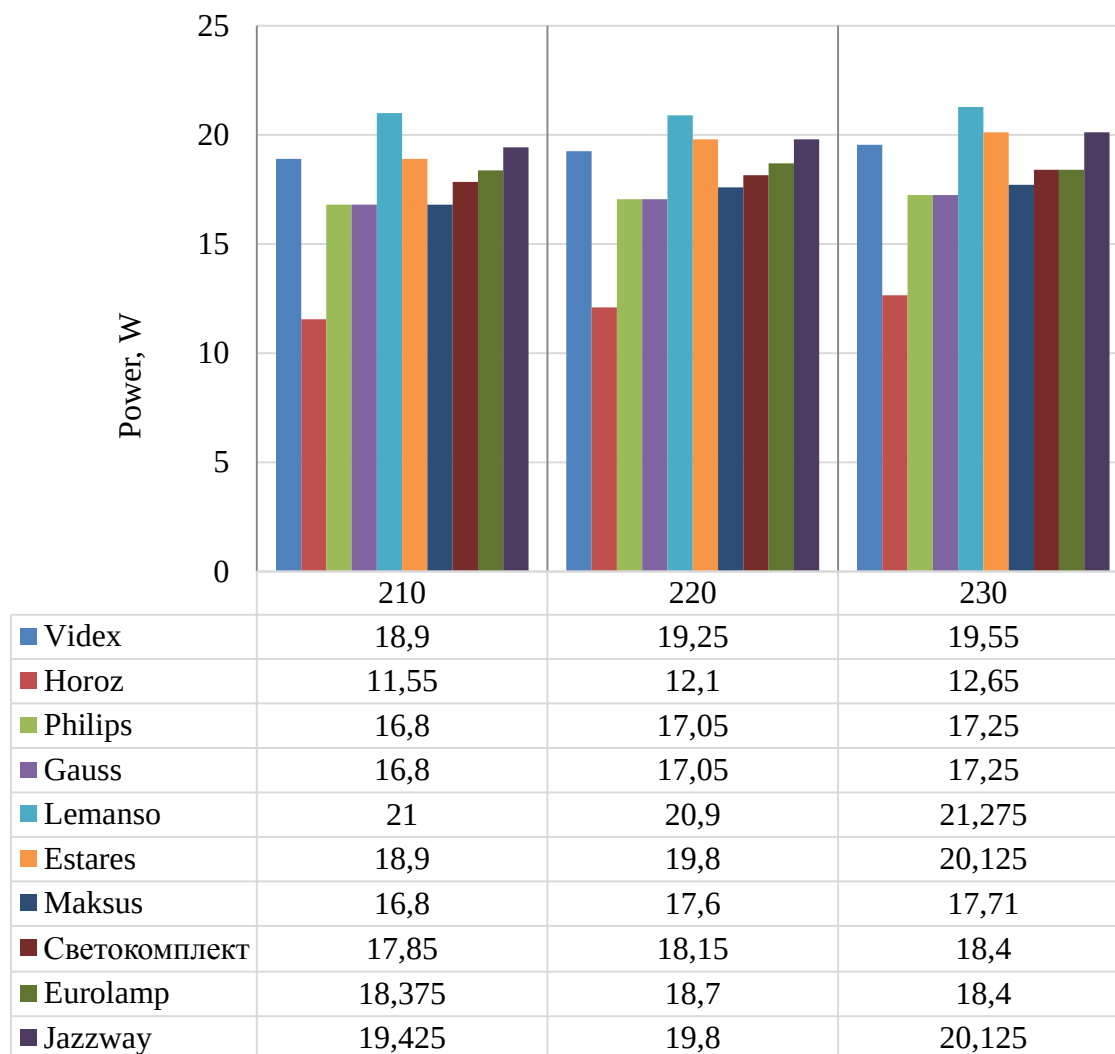
**Figure 1.** Illumination change due to the outer temperature

The change in illumination appears, and increases at a lower temperature. It is more rational to use Lemanso at low temperatures, the power consumed will not change and the illumination will increase, in our case by 31%. On an analogous light bulb above the following representatives of Maksus, Svetkomplekt, Jazz way and Estares, and I have such behavior, but in a small ratio. From the consumer's point of view, the best option for this parameter in any case has not changed, or did not significantly, the following

representatives cope perfectly with the following representatives, Philips, Gauss, Videx, Horoz and Eurolamp.

We also decided to determine what the actual power of the lamps in the operating voltage range and how it corresponds to the declared capacity of the manufacturer. To do this, a series of experiments was conducted, the results of which are summarized below.

In figure 2 graphically depicts power comparisons in the operating range.



**Figure 2.** Comparison of the operating range power

In the experiments outlined above, it is vividly demonstrated how manufacturers establish low-quality FDI or light-colored elements, which, in their turn, give a way to the characteristics that are represented by manufacturers. Only 1 in 10 lamps selected by us approximately correspond to the given parameters.

## CONCLUSIONS

The change in illumination appears, and increases at a lower temperature. It is more rational to use Lemanso at low temperatures, the power consumed will not change and the illumination will increase, in our case by 31%. On an analogous light bulb above the following representatives of Maksus, Svetkomplekt, Jazzway and Estares, and I have such behavior, but in a small ratio.

From the consumer's point of view, the best option for this parameter in any case has not changed, or did not change significantly, the following representatives cope perfectly with the following representatives, Philips, Gauss, Videx, Horoz and Eurolamp.

## REFERENCES

- Goshko T. D., Goshko M. O., Khimka S. M., Brukh O. O., Golodnyak R. I., 2013. Choosing a financial strategy as a direction of enterprise development. *Bulletin of the Kamyanets-Podilsky National University. Ivan Ogienko. Economic Sciences*. Kamyanets-Podilsky: Abetka. Issue 8: 123-125 (in Ukraine).
- Goshko T. D., Goshko M. O., Drobot I. M., Biilek I. I., 2013. Migration Policy in the Agrarian Sector of Economy. *Visnyk of*

- Lviv National Agrarian University "Agroengineering Research: Economics of AIC ". Lviv LNAU, 20 (1) : 420-423 (in Ukraine).
- Goshko M. O., Vasiliev K. M., Herman A.F., Yatsikov M. M., Levonyuk V. R.. 2013. Mathematical model of the three-phase single-phase voltage modulator of the contactless excitation system of an asynchronous generator. *Visnyk of Lviv National Agrarian University " Agro-engineering research"*. Lviv: LNAU, No. 17: 10 (in Ukraine).
- Hoshko M. 2014. The quality characteristics of electric illuminants. *IOSR Journal of Humanities and Social Science*. Vol. 19, Issue 1: 53-57 (in English).
- Goshko M.O., Khimka S.M., Syrotyuk V.M. 2015. Results of experimental study of energy-saving dispenser of loose feed. *MOTROL Motoryzacja i energetyka rolnictwa*. Lublin, No. 16D: 148-156 (in Polish).
- Goshko M. O., Khimka S. M. 2015. Investigation of the characteristics of modern electric light sources by the example of CLL. *MOTROL Motoryzacja i energetyka rolnictwa*. Lublin, Vol.17. No. 4: 61-66 (in English).
- Goshko M. 2015. Investigation of contemporary illuminants characteristics the led lamps exempl.. *ECONTECHMOD. AN INTERNACIONAL QUARTERLY JOURNAL*. Vol.4. No. 4: 63-70 (in English).
- Goshko M. 2016. Investigation of contemporary illuminants characteristics. The led lamps exempl. *ECONTECHMOD. AN INTERNACIONAL QUARTERLY JOURNAL*. Vol.5. No. 3: 205-210 (in English).
- Goshko M., Levonyuk V., Drobot I. 2016. Investigation of the characteristics of modern electric light sources on the example of lamps for external illumination. *MOTROL. Motoryzacja i energetyka rolnictwa*. Lublin, Vol. 18, No. 4. : 17-20 (in English).
- Hoshko M. 2017. Energy supply under conditions of energy deficiency – use of the security electric LED lamps. *ECONTECHMOD. AN INTERNACIONAL QUARTERLY JOURNAL*. Vol.6. No. 3: 205-210 (in English).





## EFFICIENT USE OF ASPIRATION SYSTEMS OF GRAIN AND SEED CLEANING MACHINES

Serhii Kharchenko<sup>1</sup>, Yevhen Haiek<sup>2</sup>, Tetiana Bazhynova<sup>3</sup>, Stepan Kovalyshyn<sup>4</sup>

<sup>1</sup>Poltava state agrarian university, St Skovorodi 1/3., Poltava, 36003, Ukraine

<sup>2,3</sup>State Biotechnological University, St. Alchevskih 44, Kharkiv 61000, Ukraine

<sup>4</sup>Lviv National Agrarian University, 1 V. Velykoho Str., Dubliany, 80381, Ukraine

e-mail: <sup>1</sup>kharchenko\_mtf@ukr.net, <sup>2</sup>gaekevgen@gmail.com, <sup>3</sup>tatyana2882@gmail.com,  
<sup>4</sup>[stkovalyshyn@gmail.com](mailto:stkovalyshyn@gmail.com)

**Abstract.** Obtaining high-quality grain material in the required quantities in compliance with the scaled dust content of the air in the working area is determined by the efficiency of processes, cleaning methods of the air flow, and the designs of dust collectors for grain and seed cleaning machines.

Increase in the productivity of grain and seed cleaning machines, which causes growth of the concentration of fine particles of impurities and dust, is restrained by the lack of efficiency of aspiration systems while cleaning the air flow. Classical improvement of dust collectors with aspiration systems, their separate elements, is confined and limited by design features of mobile grain separators.

Based on the analysis of research results, a method was proposed to increase the efficiency of cleaning dusty air flows from light impurities and dust on grain and seed cleaning machines by using the developed rotary cyclone with a multi-disc purifier. Increasing the efficiency of the process of cleaning dusty air flow in the dust collectors requires additional influence on the dispersed particles to ensure their intensive redistribution in the working areas. Dependences of the overall performance on parameters of the offered cyclone are established.

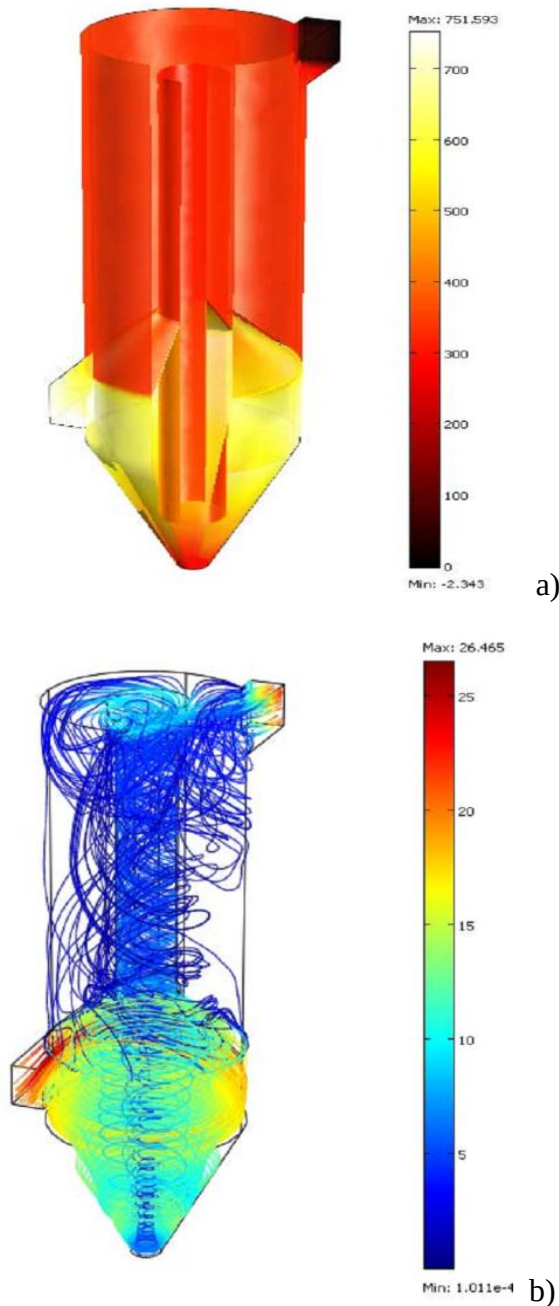
**Keywords:** cleaning processes, intermediate selection, dusty air flow, cyclone, intensification, cleaning coefficient.

### ANALYSIS OF RECENT RESEARCH

Studies of the processes, methods of cleaning the air flow and improving the efficiency of dust collection devices are outlined in the works of (Dadak 2007; Pavlyuchenko 2016; Sabirzyanova *et. al* 2017; Vasilieva *et. al* 2007; Kuts 1986; Maistruk 2000; Shushlyakov 2004; Kharchenko 2007; Aslamova 1987; Kotov B.I. *et. al* 2019; Tverdokhlib I.V. *et. al* 2016).

Dust collection using rotary dust collectors is one of the promising ways to clean the air flow. Studies of the processes, occurring inside the dust collectors, the trajectory of the air flow in the working areas are given in the works (Vetoshkin 2005). Typical schemes of movement of dusty flows in rotary dust collectors are shown in (fig.1).

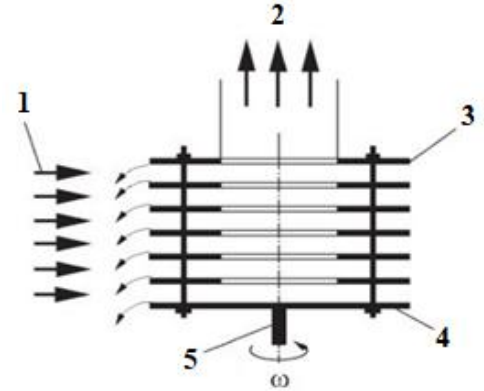
Dusty air flow is fed through the lower hole, where it acquires a vortex motion, which is a classic one for the cyclone. Further movement of the air flow is complicated by the rotation of the impeller, which creates additional centrifugal forces that create conditions for effective cleaning of the dust-gas mixture. The next stage is a complex change in the direction of rotation due to the rotation of the impeller. The efficiency of this cyclone is  $\eta = 95 \%$  with the calculated excess pressure (about 750 Pa) on the inlet connection.



**Figure 1.** Scheme of movement of pressure distribution and dusty air flow in the cyclone: a – pressure distribution; b – pressure distribution and gas flow lines at a speed of 20 m/s

Rotating disk systems (fig. 2) are widely found in gas and steam turbines, heat power engineering, power industry, chemical engineering devices, industrial mass transfer devices, etc. (Shevchuk *et. al* 2012). Dusty air flow is fed into the disk cleaner due to the

pressure generated between the disks, the dispersed particles are thrown away from the axis of the disk system. These devices provide the advantage of separating fine particles from the air flow. The disadvantage is that the system has no holes or channels for the removal of purified air flow, which forms an enhanced hydraulic resistance.



**Figure 2.** Dust collector with rotating disk cleaners: 1 – dusty air; 2 – purified air; 3 – disc with hole; 4 – solid disk; 5 – shaft; 6 – dust

Designs of direct-flow dust collectors (fig. 3) of the cyclone type for dry mechanical cleaning of gases are also well-known. The efficiency of dust capture in the presented cyclones is 70% for particles with a diameter of 10 microns and more with the hydraulic resistance not exceeding 1400 Pa (Dubynin *et. al* 2004).

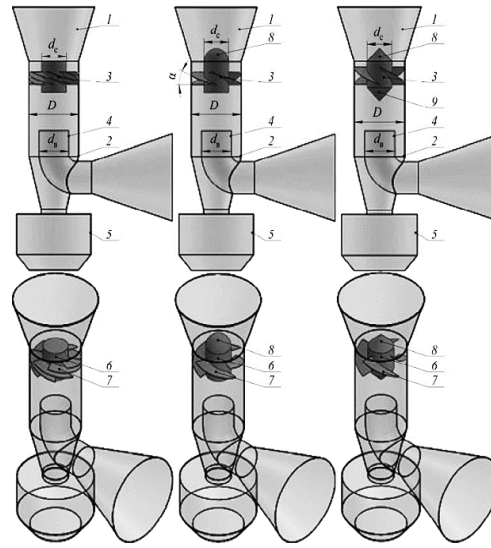
A cyclone with a transverse-flow separation zone (fig. 3, 4) is used for increasing the efficiency of air flow cleaning in (Kuznietsov 2004). The dusty air flow enters through the tangential pipe 1 in the swirler 2 of a screw type where it acquires a rotational motion. Under the influence of centrifugal force, the dispersed particles receive a radial motion in the direction from the axis to the wall of the cyclone 3, near which their concentration increases. Concentrated flow of dispersed particles when moving along the wall enters the tangential gap 5 and through it gets into the dust collector 6. The cleaned air flow is pumped out by the fan 8 through the channel 7 and removed from the device.

The disadvantage of these devices (fig. 3, 4) is the use of stationary elements, the action of

which is limited by the speed of air flow at the inlet. This creates an insufficient impulse, which is given to fine dust particles and helps to redistribute them to the periphery of the working area. The consequence is lack of efficiency of air flow cleaning. A partial solution to this negative effect is given in the construction (fig. 4), which

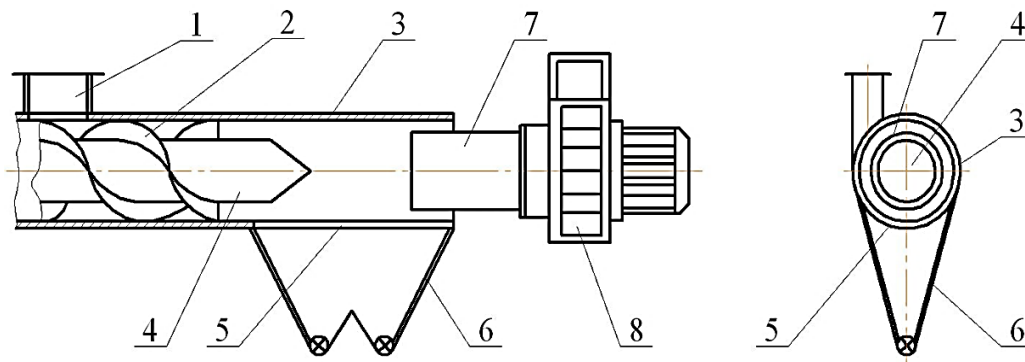
provides a fan that absorbs fine dust particles and carries them out through the outlet pipe.

Vortex dust collectors, like cyclones and rotary dust collectors, belong to centrifugal devices. Their distinctive feature is the high efficiency of air flow cleaning from fine fractions less than 5 microns.



**Figure 3.** Designs of cyclones with a swirler type "socket" and different types of fairings: 1 – inlet pipe; 2 – case of the device; 3 – swirler; 4 – outlet pipe; 5 – bunker; 6 – cylindrical part of the swirler;

7 – blades of swirler; 8 – upper fairing; 9 – lower fairing;  $d_b$ ,  $d_c$  – diameter of the exhaust pipe and the core

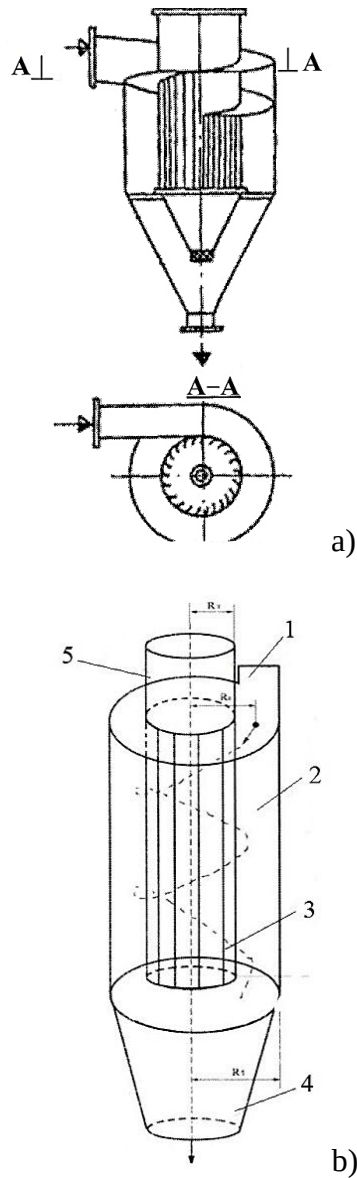


**Figure 4.** Constructive scheme of cyclone dust collector: 1 – tangential pipe; 2 – screw swirler; 3 – cylindrical case; 4 – insert; 5 – tangential gap; 6 – dust collection chamber; 7 – exhaust air duct; 8 – exhaust fan

Thus, the use of incoming flow vortices in cyclones contributes to the redistribution of

dispersed particles and increase the efficiency of air flow cleaning.

Cyclones with the division of a working area into sections, with removal of the cleared air flow or dispersed particles proved its ability in practice (figs. 5, 6).



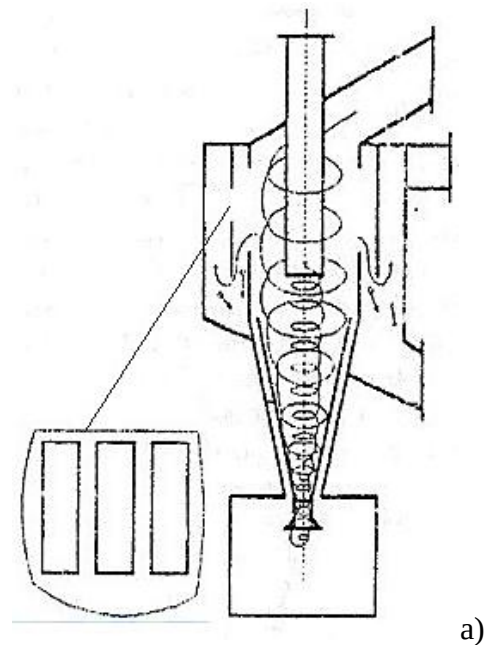
**Figure 5.** Designs of cyclones with louver elements for removal of clean air: a – centrifugal inertial dust collector designed by V.P. Kuz; b – dust collector with louver separator designed Yu.R. Dadak 1 – inlet pipe; 2 – cyclone case; 3 – louver separator; 4 – conical part of the cyclone; 5 – purified air outlet pipe

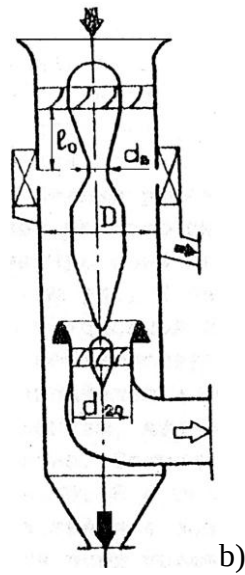
Thus, to delimit the working area in (Kotov *et. al* 2019), the authors proposed to use

louvers in cyclones (fig. 5). Installed louver separators remove clean air from the cyclone working area, while increasing the concentration of the dispersed phase and efficiency of air flow cleaning.

The dust collector designed by V.V. Maistryk (Maistryk 2000) is presented in fig. 6, a. It includes the design of the cyclone and elements of the additional removal of dispersed particles, located on the outer wall of the cyclone, by transverse slits. Due to them, there is an intermediate removal of dispersed particles, which are concentrated near the outer wall of the cyclone and are deposited in the appropriate zone. According to research, this design increases the efficiency of air flow cleaning by 12% compared to a standard cyclone ZN-15.

V.S. Aslamova (Aslamova 1987) developed the design of a direct-flow cyclone using a swirler and intermediate removal of trapped dispersed particles (fig. 6, b). This construction allowed to act comprehensively on the dispersed particles and get a significant efficiency of air flow cleaning 97...98 %, with the hydraulic resistance of 1.43 kPa.





**Figure 6.** Cyclones with intermediate selection of dispersed particles: a – construction done by V.V. Maistryk; b – construction done by V.S. Aslamova

The analysis (fig. 5, 6) shows that the intermediate removal of dispersed particles or clean air from the working area of the devices by slits or louvers improves the efficiency of air flow cleaning.

The analysis of dust collector designs (Didur *et. al* 2013) allowed to determine the following classification: mechanical devices; devices with chemical reaction; devices with the use of filters; combined devices; devices with electrical action.

When choosing a dust collector, it is important to take into account design features. Thus, dry mechanical devices are characterized by a limited scope of use by the criterion of fractional dust, have large size, but they are easy to maintain and eliminate intermittent operation, which is typical for wet devices.

Cyclones are inertial dust collectors, in which the purification of gaseous medium occurs in a rotating flow under the action of centrifugal forces. According to the National Standards of Ukraine DSTU 12.2.043-80 cyclones belong to the 4th and 5th classes of dust collectors by the criterion of efficiency, and catch particles in the size from 8 microns.

Each device has a corresponding area of application and use. The operation mode of the devices is based on one or more processes of dedusting, deposition, separation, coagulation, etc.

Main mechanisms can be identified at the core of the work of dust collectors:

- gravitational deposition, when the vertical motion of dispersed particles is caused by gravity;

- inertial separation, when the output of dispersed particles from the curved lines of air flow occurs due to the forces of inertia;

- separation under the action of centrifugal forces, when the dispersed particles are affected by centrifugal forces and there is redistribution of particles to the peripheral walls of the device;

- sticking effect, coagulation starts when dust particles combine with each other and their properties change;

- filtration when dispersed particles are trapped;

- magnetic control by the deposition elements, when the change in the trajectory of the charged dispersed particles occurs in the magnetic field of the device.

Therefore, in view of the arguments stated above, it is obvious that the most promising way to increase the efficiency of air flow cleaning is the use of centrifugal dust collectors. They have high cleaning efficiency with low hydraulic resistance, do not require periodic maintenance, additional energy costs, they are easy to manufacture and install.

The simplest centrifugal dust collectors of rotational action have the following mechanism: an impeller and a casing (dust receiver) (fig. 7) (Ivanov *et. al* 2014). To increase the efficiency of the cleaning process, centrifugal dust collectors are equipped with the following elements: discs, blades, etc. for flow direction (fig. 7, a, b, e), partitions, chambers, etc. for removal of dispersed particles from the working area (fig. 7, c, d).

The installation of additional elements in cyclones that intensify the redistribution of dispersed particles is shown in (Kuznietsov *et. al* 2009) (fig. 7). The cyclone has double filtration

channels, which provide vortex flow and separation of fine particles up to  $1\ \mu\text{m}$  (Tarasenko *et. al* 2017).

centrifugal dust collector designed by Rosenkrantz

### OBJECTIVE OF THE STUDY

The objective of the study is to determine a promising way to increase the efficiency of the process of the dusty air flow cleaning by aspiration systems of grain and seed cleaning machines while using the developed cyclone with a purifier with optimal parameters.

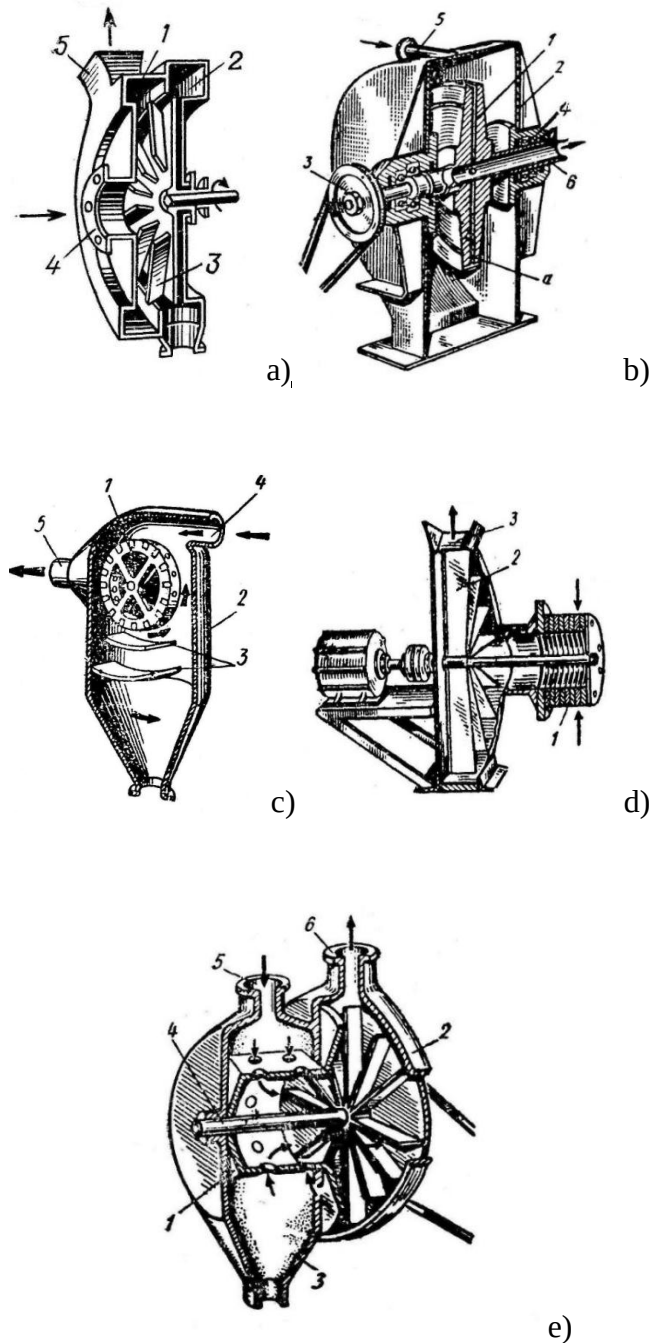
### RESULTS AND DISCUSSION

To increase the efficiency of the process of the dusty air flow cleaning, it is proposed to use a promising method by combining devices with different principles of operation with stage cleaning and intermediate removal of dispersed particles (fig. 8). (Kharchenko *et. al* 2014).

For this purpose, an active vortex fan 4, an intermediate particle selection through louvers 7 and a multi-disc purifier 5 were used.

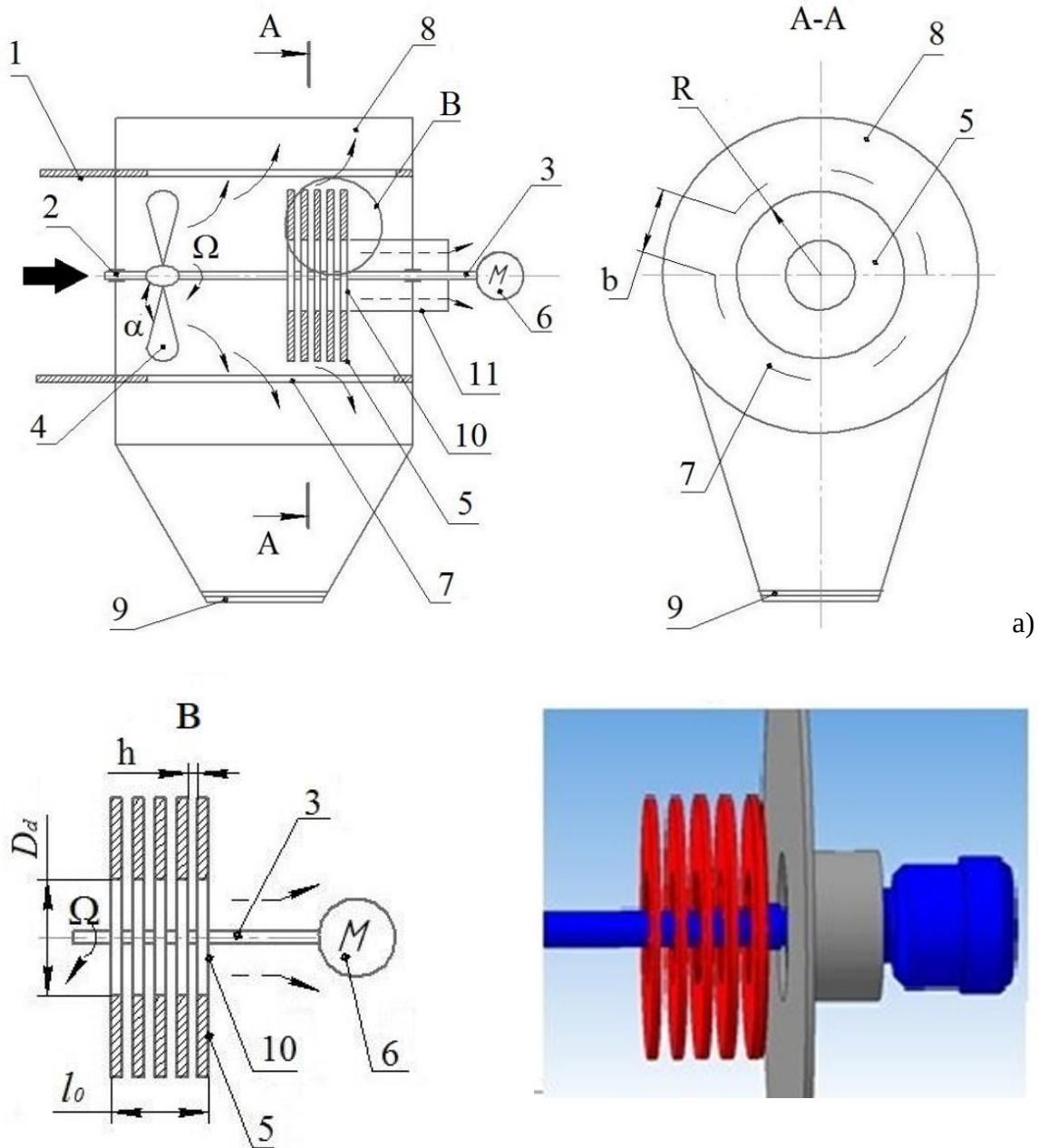
The proposed design of the dust collector includes a cylindrical housing 1 with holes 7 (fig. 8, a), in which a shaft 3 with a swirler 4 and a disk purifier 5 are mounted on the holding blocks 2. The shaft rotates by an electric motor 6. The holes 7 of the housing 1 are installed at an angle to the axis of rotation of the shaft 3 and divide the main working area from the deposition chamber 8, which is installed around the housing 1. A sluice valve 9 is installed in the lower part of the deposition chamber 8.

A multi-disc purifier 5 (fig. 8, b) consists of a set of disks of the same diameter, in the central part of which there are holes 10. The air flow is removed from the cyclone through the outlet pipe 11. At a certain gap a layer is formed, from which due to the centrifugal force the particles are separated and sent to the dust chamber 8. This helps to remove effectively fine particles from the air flow between the rotating disks.



**Figure 7.** Centrifugal dust collectors:  
a – centrifugal dust collector (separator);  
b – centrifugal dust collector CRP; c – centrifugal dust collector designed by Yakimov; d – dust collector designed by Grishchenko; e –





**Figure 8.** Constructive scheme of the developed rotary cyclone with a multi-disc purifier: a – general scheme; b – multi-disc purifier 1 – housing; 2 – holding blocks; 3 – axle; 4 – swirler; 5 – disk purifier; 6 – electric motor; 7 – louvers; 8 – deposition chamber; 9 – sluice valve; 10 – holes of disks of purifier; 11 – outlet pipe

Dusty air flow enters the cyclone on the swirling fan blade, which rotates. Centrifugal forces direct the dispersed particles to the walls of the housing and through the holes to the deposition chamber. The cleaned air flow leaves the dust collector through the central holes of the disks of the purifier, which also rotate. The dispersed particles, remaining in the flow due to

the pressure formed between the disks, are discarded through the holes to the deposition chamber.

The working process of air flow cleaning in the proposed design of a rotary cyclone with a purifier consists of two stages: basic cleaning with intermediate removal of dispersed particles and final purification.



The first stage: moving dusty air flow is cleared from coarse particles of impurity due to inertia and gravity, it leaves through the louvers to the deposition chamber. The second stage: fine dust particles, that remain moving in the dusty air flow, fall on the multi-disc purifier. The disks are installed at a distance from each other, and do not allow dust particles to pass, throwing them through the louvers to the deposition zone. The cleaned air flow passes between the disks and through the central hole inside the disks to the outlet pipe.

## RESULTS OF THE RESEARCH

Studies of the efficiency of the developed rotary cyclone involved determining the coefficient of purification of dusty air flow with varying values of the following important factors: air flow velocity  $U_0$ , the distance between the disks  $h$ , angle of inclination of the swirler blades  $\alpha$ , the width of the louver opening  $b$ , motor rotor speed  $\Omega$ ; the number of discs of purifier  $n$ .

The research proved the dependences of the cleaning coefficients of the developed rotary cyclone on its design and technological parameters (fig. 9 – 11).

**Table 1.** Research of the coefficients of purification of the developed rotary cyclone from the air flow velocity

| Air flow velocity<br>$U_0$ , m/s | Cleaning coefficient $\eta$ , % |                   |  | Cyclone design parameters (fig.8)                            |
|----------------------------------|---------------------------------|-------------------|--|--------------------------------------------------------------|
|                                  | $\Omega=1000$ rpm               | $\Omega=2000$ rpm |  |                                                              |
| 6                                | 93,1                            | 91,1              |  | $n=6$ pcs.;<br>$h=1$ mm;<br>$\alpha=20^\circ$ ;<br>$b=20$ mm |
| 7                                | 93,2                            | 91,2              |  |                                                              |
| 8                                | 93,3                            | 91,4              |  |                                                              |
| 9                                | 93,4                            | 91,5              |  |                                                              |
| 10                               | 93,5                            | 91,8              |  |                                                              |
| 11                               | 93,6                            | 92,1              |  |                                                              |
| 12                               | 93,7                            | 92,5              |  |                                                              |
| 13                               | 93,8                            | 92,8              |  |                                                              |

Analysis of research (table 1) shows that the maximum efficiency of the air flow cleaning process is  $\eta=93,1...93,8$  %, at air flow velocity  $U_0 = 6...13$  m/s and at shaft speed  $\Omega = 1000$  rpm.

**Table 2.** Research of the coefficients of purification of the developed rotary cyclone from the air flow velocity

| Air flow velocity<br>$U_0$ , m/s | Cleaning coefficient $\eta$ , % |                   |                   | Cyclone design parameters (fig.8)                           |
|----------------------------------|---------------------------------|-------------------|-------------------|-------------------------------------------------------------|
|                                  | $\alpha=10^\circ$               | $\alpha=20^\circ$ | $\alpha=30^\circ$ |                                                             |
| 6                                | 90,2                            | 91,1              | 89,0              | $n=6$ pcs;<br>$b=20$ mm;<br>$h=1$ mm;<br>$\Omega =1000$ rpm |
| 7                                | 90,5                            | 91,3              | 89,1              |                                                             |
| 8                                | 90,7                            | 91,5              | 89,2              |                                                             |
| 9                                | 90,8                            | 91,7              | 89,4              |                                                             |
| 10                               | 91,0                            | 92,0              | 89,5              |                                                             |
| 11                               | 91,2                            | 92,1              | 89,9              |                                                             |
| 12                               | 91,8                            | 92,5              | 90,1              |                                                             |
| 13                               | 92,0                            | 92,8              | 90,5              |                                                             |

Thus, within the range of the studied air flow rate (table 2)  $U_0 = 6...13$  m/s, maximum cleaning coefficient is  $91,1...92,8$  %, which is  $2,3...2,5$  % more than at  $\alpha = 30^\circ$

**Table 3.** Research of the coefficients of purification of the developed rotary cyclone from the distance between the disks of the purifier

| The distance between the disks<br>$h$ , mm | Cleaning coefficient $\eta$ , % |                |                | Cyclone design parameters (fig.8)                                      |
|--------------------------------------------|---------------------------------|----------------|----------------|------------------------------------------------------------------------|
|                                            | $U_0 = 6$ m/s                   | $U_0 = 10$ m/s | $U_0 = 13$ m/s |                                                                        |
| 0,5                                        | 90,0                            | 89,2           | 89,0           | $n=6$ pcs.;<br>$\alpha=20^\circ$ ;<br>$b=15$ mm;<br>$\Omega=1000$ rpm; |
| 0,75                                       | 91,9                            | 91,2           | 90,8           |                                                                        |
| 1,0                                        | 92,4                            | 91,5           | 91,1           |                                                                        |
| 1,25                                       | 91,1                            | 90,2           | 90,1           |                                                                        |
| 1,5                                        | 88,3                            | 87,7           | 87,9           |                                                                        |

Analysis of the dependences (table 3) shows that the distance between the disks of the purifier, which provides maximum efficiency of the developed rotary cyclone  $\eta = 90,1...92,4$  %, is  $h = 0,75...1,25$  mm.

Analysis of experimental studies proved that increasing the velocity of air flow in the ranges under study increases the cleaning coefficient of the developed rotary cyclone from  $4...4,8\%$  to  $89...93,8$  %. The obtained parameters of the rotary cyclone are: the angle of the blades  $\alpha = 20^\circ$ , the rotor speed  $\Omega = 1000$

rpm, the distance between the disks of the purifier  $h = 1$  mm.

The hydraulic resistance of the developed rotary cyclone was experimentally determined according to the method and pressure drop before and after using the device with variation of significant parameters of the developed rotary cyclone (table 4).

**Table 4.** Research of the hydraulic resistance of the developed rotary cyclone from the air flow velocity

| Air flow velocity<br>$U_0$ , m/s | Hydraulic resistance, $\Delta P$ |              |              | Cyclone design parameters                                            |
|----------------------------------|----------------------------------|--------------|--------------|----------------------------------------------------------------------|
|                                  | $n=3$<br>pcs                     | $n=6$<br>pcs | $n=9$<br>pcs |                                                                      |
| 5,0                              | 185                              | 60           | 40           | $\alpha=30^\circ$ ;<br>$h=1$ mm;<br>$b=15$ mm;<br>$\Omega=1000$ rpm. |
| 7,5                              | 270                              | 85           | 65           |                                                                      |
| 10,0                             | 310                              | 100          | 70           |                                                                      |
| 12,5                             | 375                              | 110          | 65           |                                                                      |
| 15,0                             | 380                              | 118          | 62           |                                                                      |

Analysis of research (table 4) proved that increasing the speed of air flow  $U_0 = 5...15$  m/s and values of the parameters of the developed rotary cyclone, in the ranges under study, increases the hydraulic resistance in the range of 40... 380 PA.

**Table 5.** Research of the coefficient of purification of the developed rotary cyclone from the size of dispersed particles

| The size of the dispersed particles $d_s$ , $\mu\text{m}$ | Cleaning coefficient $\eta$ , % |                 | Cyclone design parameters                                  |
|-----------------------------------------------------------|---------------------------------|-----------------|------------------------------------------------------------|
|                                                           | $U_0=10$<br>m/s                 | $U_0=13$<br>m/s |                                                            |
| 1                                                         | 5                               | 7               | $n=6$ pcs;<br>$b=15$ m;<br>$h=1$ mm;<br>$\Omega=1000$ rpm. |
| 20                                                        | 60                              | 37              |                                                            |
| 40                                                        | 85                              | 75              |                                                            |
| 60                                                        | 92                              | 88              |                                                            |
| 80                                                        | 97                              | 96              |                                                            |
| 100                                                       | 98                              | 98              |                                                            |

To receive a complete picture of the degree of purification efficiency of the dust flow, the fractional purification coefficient was determined (table 5) for the fractions of dispersed particles under study.

Analysis of research (table 5) proved that at the speed of air flow in the developed rotary cyclone  $U_0 = 10...15$  m/s the cleaning coefficient is  $\eta = 5...98$  % for dispersed particles in the size up to 90  $\mu\text{m}$ . It must be noted that the developed rotary cyclone captures dispersed particles  $d_s = 1...40$   $\mu\text{m}$  with efficiency  $\eta = 5...87$  %, which significantly affects the intensification of the process of air flow cleaning in mobile grain separators.

## CONCLUSIONS

1. The dependences of the cleaning coefficient on the air flow velocity were experimentally proved. Increasing the velocity of the air flow in the range under study increases the cleaning coefficient of the developed rotary cyclone by 4...4,8 % to  $\eta = 91...93,8$  %. The ranges of variation of the obtained parameters of the rotary cyclone were: the angle of inclination of the blades  $\alpha = 20^\circ$ , rotor speed  $\Omega = 1000$  rpm, the distances between the disks of purifier  $h = 1$  mm.

2. Identification of the hydraulic resistance of the developed rotary cyclone with the establishment of the influence of design and technological parameters was experimentally proved. Provided maximum efficiency and minimum hydraulic resistance, the range of disc numbers was determined as  $n = 6$  pcs. The range of variation of the hydraulic resistance of the developed rotary cyclone with the purifier, taking into account its defined rational parameters, was 130...180 PA.

## REFERENCES

- Dadak Yu. R. 2007 Chyslova realizatsiia matematychnoi modeli rukhu chastynky pylu u pylovlovliuvachi z zhaliuziinym vidokremliuvachem. *Naukovyi visnyk NLTU Ukrainy: zb. nauk. pr.*, Vol. 17.4, P. 254–259.
- Pavlyuchenko K. V. 2016. Eksperimentalnoe issledovanie pnevmaticheskogo separatora zerna s naklonnyim vozdushnym potokom.

- Elektronnyi nauchno-metodicheskii zhurnal Omskogo GAU. № 3(6).* Available online at: <https://docplayer.ru/52830325-Eksperimentalnoe-issledovanie-pnevmaticheskogo-separatora-zerna-s-naklonnym-vozdushnym-potokom.html>
- Sabirzyanova L. R., Uriev A. A., Harkov V. V., Nikolaev A. N. 2017. Ochistka promyshlennyykh gazovykh vyibrosov ot pyli v polykh vihvyykh apparatah. *Vestnik Kazanskogo tehnologicheskogo universiteta*, №8, P. 81-85.
- Vinogradov S. S., Vasileva I. A. 2007. Problemy klassifikatsii gazoochistnogo oborudovaniya i ego vyibora. *Ekologiya promyshlennogo proizvodstva*, №. 2, P. 18-23.
- Kuts V. P. 1986. Povyshenie effektivnosti pyileulavlivaniya v tsentrobezhno-inertsionnykh pyileotdelitelyakh s zhalyuziynym otvodom vozduha: avtoref. dis. na soiskanie nauk stepeni kand. tehn. nauk:05.17.08. Moscow, 24 p.
- Maistruk V. V. 2000. Rozdilennia zapylenykh haziv u tsyklonakh z promizhnym vidvedenniam tverdoi fazy: avtoref. dys. na zdobuttia nauk. stupenia kand. tekhn. nauk:05.17.08. Lviv, 18 p.
- Shushliakov O. V. 2004. Pidvyshchennia efektyvnosti sukhoi ochystky haziv za dopomohoiu inertsiiynykh aparativ: avtoref. dys. na zdobuttia nauk. stupenia d-ra tekhn. nauk:05.23.03. Kharkiv, 37 p.
- Kharchenko S. O. 2007. Obhruntuvannia parametriv protsesu ochyshchennia povitrianooho potoku pyloosadzhuvalnoiu kameroiu vibrovidtsentrovykh zernovykh separatoriv: avtoref. dys. na zdobuttia nauk. stupenia kand. tekhn. nauk: 05.05.11 / KhNTUSH im. P. Vasylenka. Kharkiv, 20p.
- Aslamova V. S. 1987. Intensifikatsiya protsesa separatsii v pryamotochnom tsyklone i ventilyatore-pyileulovitele: avtoref. dis. na soiskanie kand. tehn. nauk:05.17.08. Moscow, 16 p.
- Kotov B., Spirin A., Kalinichenko R., Bandura V., Polievoda Y., Tverdokhlib I. 2019. Determination the parameters and modes of new heliocollectors constructions work for drying grain and vegetable raw material by active ventilation. *Research in Agricultural Engineering. Vol. 65. № 1.* P. 20-24.
- Tverdokhlib I. V. 2016. Obhruntuvannia tekhnolohii ta konstruktyvno-rezhymnykh parametriv terkovo-separuiuchoho bloku dlia obrobky vorokhu trav: avtoref. dys. na zdobuttia nauk stupenia kand. tekhn. nauk: 05.05.11. Vinnytsia, 24 p.
- Vetoshkin A. G. 2005. Protsessyi i apparaty pyileochistki: uchebnoe posobie. Penza: Izd-vo Penz. gos. n-ta., 210 p.
- Shevchuk I. V., Halatov A. A. 2012. Teploobmen i gidrodinamika v polyah massovykh sil: obzor rabot, vyipolnennykh v ITTF NAN Ukrainyi. Part 4. *Vraschayuschiesya sistemyi Prom. teplotekhnika*, T. 34, №4, P. 5–19.
- Dubynin A. I., Maistruk V. V., Havryliv R. B., Maistruk I. V. 2004. Zmenshennia enerhovytrat na pyloochyshchennia shliakhom vykorystannia pylovlovliuvachiv z priamotochnoiu zonoiu rozdilennia. *Naukovyi visnyk NLTU Ukrainy*, № 4, P. 128–130.
- Kuznietsov S. I. 2015. Kompleksne ochyshchennia hazovykh vykydiv teploenerhetychnykh pidpriemstv vid pylu, dvoosydu sulfuru i monooksydu karbonu: avtoref. dys. na zdobuttia nauk. stupenia kand. tekhn. nauk: 21.06.01: Kharkiv, 25 p.
- Didur V. A., Chebanov A. B. 2013. Obhruntuvannia konstruktsiino-tekhnolohichnykh parametriv pnevmoseparatora z pylovlovliuvalnym prystroiem. *Tekhnika i tekhnolohii APK nauk.-vyrob. zhurn. Ukr. n.-d. in-t prohn. ta vyprov. tekhn. i tekhnol. dlia s.-h. vyrva im. L. Pohoriloho*, № 11, P. 6-8.
- Ivanov V. S., Suslov D. Yu. 2014. Tendentsii razvitiya obespyilivayuschih apparatov tsiklonnogo tipa. *Sovremennyye naukoemkie tekhnologii*, № 7(2), P. 68–70.
- Kuznietsov S. I., Mykhailik V. D., Rusanov S. A., Kuznietsov S. I., Mykhailik V. D.,

- Rusanov S. A. 2009. Modeliuvannia roboty vysokoefektyvnoho tsyklonno-rotatsiinoho pylovlovliuvacha. *Visnyk Khersonskoho natsionalnoho tekhnichnoho universytetu*. № 3(36), P. 30-35.
- Tarasenko A. P., Orobinsky V. I, Gievsky A. M., Tarabrin D. S., Annenkov M. S. 2017. Obosnovanie printsipialnoy shemyi vozdushno-reshetnogo separatora semyan. *Vestnik Voronezhskogo gosudarstvennogo agrarnogo universiteta*. № 4, P. 95-102.
- Kharchenko S. A., Gaek Ye. A. 2014. Povyishenie effektivnosti ochistki zapyilyonnogo vozdushnogo potoka razrabotannyim tsiklonom aspiratsionnyih sistem zernoochistetelnyih mashin. *Materialy naukovoï konferentsii studentiv Sumskoho NAU 1-8.11*. Sumy, P. 62.



## PROTEOLYSIS OF DIFFERENT VARIETIES OF BARLEY DEPENDING ON SEED TREATMENT BY MONOCHROMATIC OPTICAL RADIATION OF THE RED RANGE

Oksana Pankova<sup>1</sup>, Kirill Sirovitskiy<sup>2</sup>, Serhii Kharchenko<sup>3</sup>

<sup>1</sup>Kharkov National Automobile and Highway University, Ukraine, Kharkiv, Y. Mudrogo str., 25.

<sup>2</sup>State Biotechnological University, Ukraine, Kharkiv, Moskovskiy Ave., 45,

<sup>3</sup>Poltava State Agrarian University, Ukraine, Poltava, Skovorody str., 1/3,

e-mail: <sup>1</sup>pankova\_oksana@ukr.net, <sup>2</sup>gaver89@ukr.net, <sup>3</sup>kharchenko\_mtf@ukr.net

**Abstract.** The article presents the results of studying the protein content and proteolysis in germinating seeds of different barley varieties depending on its treatment with monochromatic optical radiation of the red range (660 nm, 730 nm), which activates the phytochrome system. The obtained results suggest that the hydrolytic decomposition of reserve protein is influenced by the phytochrome system, which activates protein metabolism in germinating seeds. However, there is a difference in protein content and protease activity under the influence of seed treatment of the study varieties, what is evidence of the variety specificity of the studied processes.

**Key words:** barley, monochromatic optical radiation, phytochrome, photomorphogenesis, RL (red light), FRL (far red light), proteolysis, protein content, hydrolytic decomposition of substances.

### THE FORMULATION OF THE PROBLEM

It is known that the use of different types of pre-sowing seed treatment can significantly accelerate the activation of metabolic systems and regulatory systems. At some stages of plant cell ontogenesis, the action of exogenous factors leads to changes in self-regulatory factors. This leads to structural and metabolic reorganization, changes in the physiological state of cells and, as a result, - stimulation of plant growth and development (Kalinin 1986). One of such exogenous factors is optical radiation - light. Light - is the material and energy base for the implementation of genetic programs of autotrophic plants, acts as an external signal due to which the interaction of the genome with the environment is realized (Yakushenkova *et. al* 2001).

Monochromatic optical radiation due to photoregulatory low-energy reactions,

stimulating other pigments than chlorophyll, control the individual development of the plant. One of them is phytochrome, which absorbs light in the red region of the optical spectral range. Phytochrome can exist in two forms, which are responsible for the absorption of biologically active light at 660 and 730 nm, and their interconversion initiates a further chain of events (Volotovskiy 1992; Voskresenskaya 1987; Kulaeva 2001).

One of the important and difficult stages in the ontogenesis of plants is the germination of seeds. This period is characterized by the mobilization of reserve nutrients and especially by intensive metabolism, in the result of which the activity of redox and hydrolytic enzymes significantly increases and the content of reserve nutrients reduces (Ovcharov 1964).

The aim of the work is to study the dependence of proteolysis in germinating seeds of different varieties of barley on seed treatment with monochromatic optical radiation of the red range.

### MAIN MATERIAL

Two varieties of spring barley (*Hordeum vulgare* L.) were used as research objects: Anabel and Pasadena. The originator of the Anabel variety is Saaden Union (Germany), the originator of the Pasadena variety is LP (Germany).

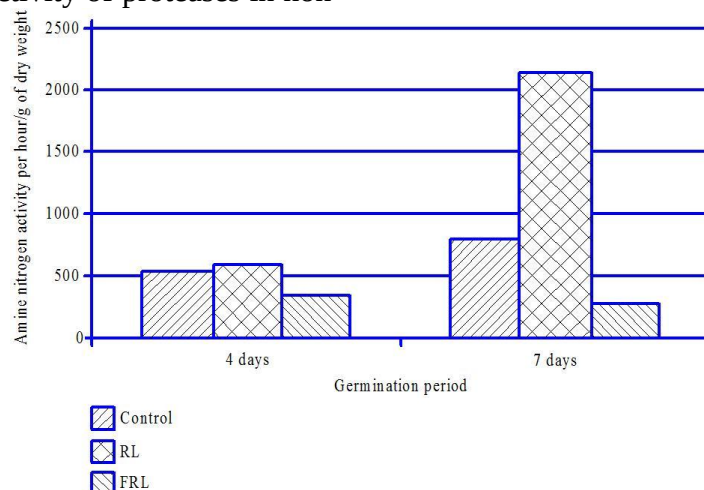
Before processing, barley seeds were soaked in distilled water for 2 hours and placed in a germinator on a filter paper. 50 g of seeds were placed in each germinator. The germinators were placed in a thermostat with  $t = 25^{\circ}\text{C}$  for 6 days. For analysis, we took plants of 4 days and 7 days. Seedlings were irradiated on the 4th day for 10 minutes by red light (RL) ( $\lambda = 660 \text{ nm}$ ), far red light (FRL) ( $\lambda = 730 \text{ nm}$ ). No irradiated seedlings were used for control.

Protein content and proteolytic activity were determined in the embryo. Proteolytic activity was determined by the rate of autolysis (by increasing amine nitrogen). Protein was determined by the Lowry method. (Ermakova 1987). The results are processed statistically (Atramentova *et. al* 2008).

## RESULTS AND DISCUSSION

The results showed that in the variety Anabel (Fig. 1), the activity of proteases in non-

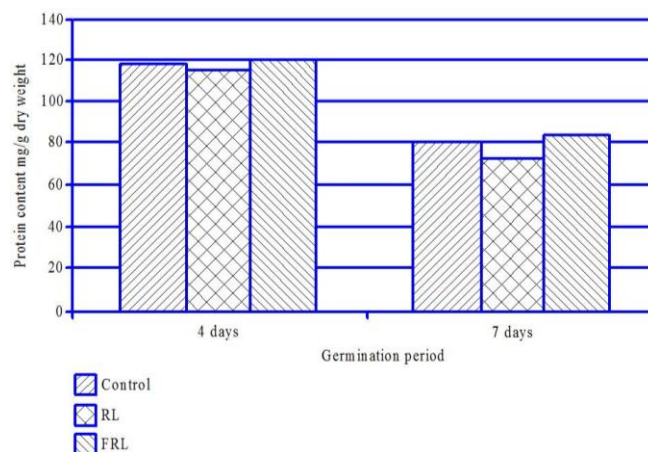
irradiated seeds, as well as when irradiated with RL on the fourth day was the same, and when irradiated with FRL - lower than in other versions of the experiment. On the seventh day of germination, the activity of proteases increased in the control and under the action of the RL, but did not change under the influence of the FRL. The activity of enzymes on the seventh day of germination was very high in seeds irradiated with RL, and the lowest in seeds irradiated with FRL.



**Figure. 1.** The activity of proteases in the seeds germ of the variety Anabel depending on the treatment of seeds with monochromatic optical radiation of different spectral range.

The protein content (Fig. 2) on the fourth day of germination was the same in all variants of the experiment. On the seventh day in the non-irradiated and irradiated seeds, the protein content decreases compared to the data on the fourth day of germination. This is probably due to the degradation of the reserve protein for the formation of the seedling during germination.

On the seventh day, the protein content in the seed germ was slightly lower when irradiate by the RL than the content in the non-irradiated seed and when irradiated with the FRL. In the last two variants, the protein content was the same. Thus, the RL most stimulates the protein degradation during seedling growth.

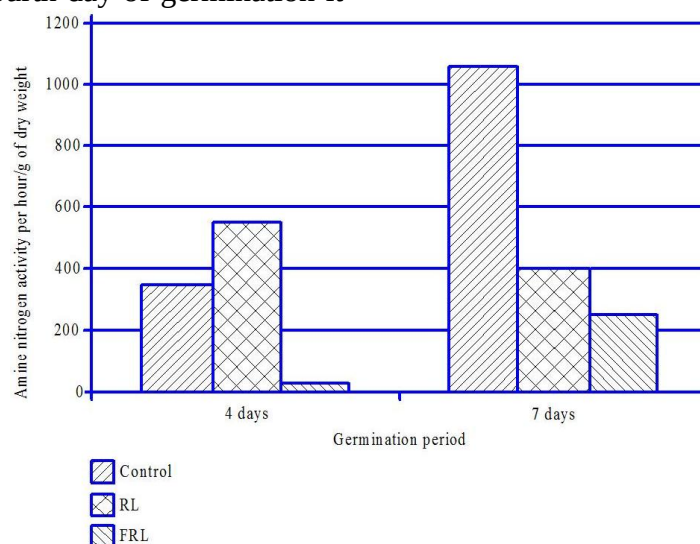


**Figure. 2.** Protein content in the germ of Anabel seeds depending on the treatment of seeds with monochromatic optical radiation of different spectral range.

Thus, the obtained data give grounds to establish that monochromatic optical radiation of the red range causes increased hydrolytic decomposition of protein in the seeds of the variety Anabel. This is most evident when RL irradiating.

The study of the proteolytic enzymes activity in the seeds of Pasadena variety (Fig. 3) showed that on the fourth day of germination it

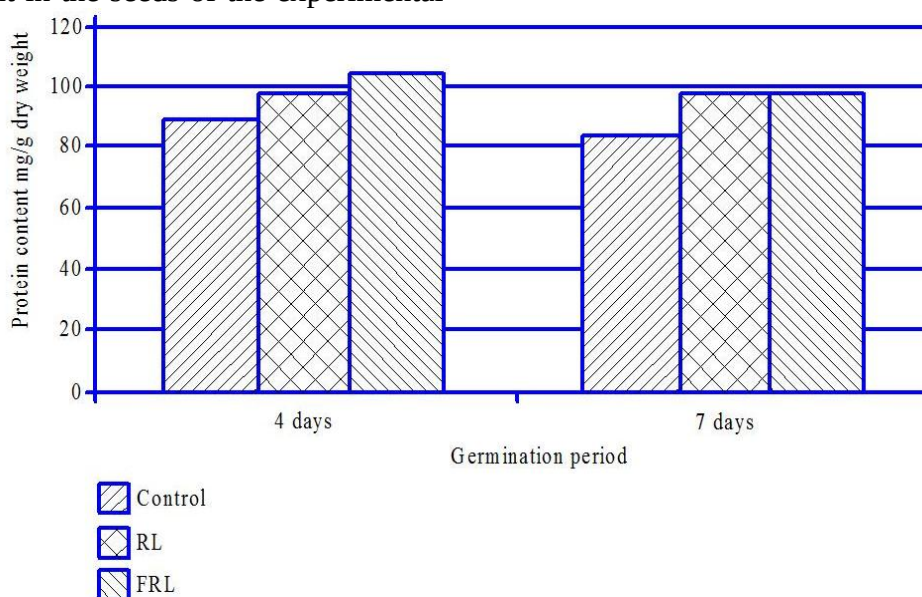
was significantly higher when irradiated with the RL, and significantly lower when irradiated with FRL than in the non-irradiated seed. On the seventh day of germination, the activity of enzymes in irradiated seeds was much lower than in non-irradiated. Irradiation of FRL inhibited the proteases activity, compared with the activity in other variants of the experiment.



**Figure. 3.** Activity of proteases in the germ of Pasadena seeds depending on the treatment of seeds with monochromatic optical radiation of different spectral range.

Determination of the protein content in the seeds of the Pasadena variety (Fig. 4) showed that in the non-irradiated seed and when irradiated with the RL and the FRL, it was the same. On the seventh day of germination, the protein content in the seeds of the experimental

variants decreased compared to the content on the fourth day of germination. The lowest protein content was in non-irradiated seeds. In the variants with irradiation, it was almost the same.



**Figure. 4.** Protein content in the germ of Pasadena seeds depending on the treatment of seeds with monochromatic optical radiation of different spectral range.



Thus, it is possible to assume that the activity of proteases in Pasadena seeds, as well as in Anabel variety (Figs. 1, 2), depends on the treatment of seeds with monochromatic optical radiation of the red range, which activates the phytochrome system. The hydrolytic decomposition of protein is most affected by radiation from the FRL (Fig. 3). The protein content in the seeds of Pasadena variety when irradiated does not change significantly (Fig. 4).

### CONCLUSIONS

The dependence of proteolysis in barley seeds on treatment with monochromatic optical radiation of the red range found in our experiments is explained as follows. It is known that the stimulating effect of seed irradiation occurs as a result of action on the membrane. Due to this, a number of enzymes is activated, oxidative enzymatic processes is intensified, mobilization of nutrients begins faster, hydrolysis of complex endosperm reserves to easier is intensified, which easier to assimilate by germ and seedlings (Shahov 1971).

However, there is variety specificity for protein content and activity of proteases. A variety within a species is a genotype with a specific type of metabolism. It is due to genotypic specificity, the individuality of a variety and a species is possible, which occurs at the morphological and metabolic levels. The genotype at the level of a variety or species is characterized by a specific metabolism, which determines the qualitative and quantitative composition of the products of life at the biochemical level. It is probable the reason for the difference in the results of the studied varieties (Dragavtsev 1997, Dragavtsev 2000).

### REFERENCES

Atramentova L.O., Utevskaia O.M. 2008. Statistical methods in biology. Horlivka: Lichtar Publishing House, 248 p.

- Volotovskiy I.D. 1992. Phytochrome is a regulatory photoreceptor of plants. Moscow: Science and Technology, 168 p.
- Voskresenskaya N.P. 1987. Photoregulatory reactions and activity of the photosynthetic apparatus *Plant physiology*, Vol.34, Issue. 4., M.:Science, P. 669-683.
- Dragavtsev V.A. 1997. Ecological and genetic screening of the gene pool and methods of constructing varieties of agricultural plants in terms of yield, stability and quality: Method. Recommendations (new approaches). St. Petersburg, 50 p.
- Dragavtsev V.A. 2000. Some fundamental approaches in ecological genetics of plants. *Agricultural biology*, № 1, P. 34
- Kalinin F.L. 1986. Theoretical foundations of growth management, development and productivity of plants with endogenous growth regulators. *Physiology and biochemistry cult. plants*, V. 18, № 6., P. 537-555.
- Kulaeva O.N. 2001. How light regulates plant life. *Sorovsky educational journal*, V. 7, № 1, P. 6-12.
- Ermakova A.I. 1987. Methods of biochemical research of plants. Leningrad: Agropromizdat. 430 p.
- Shahov A.A. 1971. Pulse stimulation of plants. Ed.. Science.
- Ovcharov K.E. 1964. Plant vitamins. Moscow: Kolos, 250 p.
- Yakushenkova T.P., Loseva N.L., Albyev A.Yu. 2001. Light of different spectral composition and resistance of spring wheat seedlings under the action of superoptimal temperature. *Bulletin of the Bashkir University*, №2 (1), P.94-96.
- Friend D.J.C. 1994. Interaction of red and far-red radiation with the vernalization process in winter rye. - Plant research institute. Canadian department of Agriculture, Ottawa, Canada, 134 p.

## PROSPECTS FOR INCREASING THE EFFICIENCY OF PNEUMATIC SEPARATION CHANNELS IN CLEANING GRAIN AND SEED MATERIALS

Serhii Kharchenko<sup>1</sup>, Vita Lytvynenko<sup>1</sup>, Stepan Kovalyshyn<sup>2</sup>

<sup>1</sup>*Poltava State Agrarian University, 1/3, Skovorody Str., Poltava, 36003, Ukraine*

<sup>2</sup>*Lviv National Agrarian University, 1 V. Velykoho Str., Dubliany, 80381, Ukraine*

*e-mail: <sup>1</sup>kharchenko\_mtf@ukr.net, <sup>2</sup>stkovalyshyn@gmail.com*

**Abstract.** The technological process of most universal grain and seed cleaning machines consists of the separation of components by aerodynamic characteristics on the pneumatic separation channels and the separation of components by size on the sieves. The restraining factor in further increasing the productivity of grain and seed cleaning machines is the imperfect design of pneumatic separation channels. The analysis carried out made it possible to determine the basic designs of pneumatic separating channels, their working elements and intensifying devices. This allowed creating a classification of pneumatic separation channels according to various structural, technological and functional features.

The conducted system analysis established that one of the factors affecting the efficiency of cleaning grain or seed materials is the uniformity of loading of the pneumatic separation channel along its width. To determine the degree of significance of this factor, a research methodology has been developed. The description of conducting experimental researches is given, mathematical expressions for determining the uniformity of the supply of grain and seed materials are established. A list of design and technological parameters and properties of grain (seed) mixtures, which affect the efficiency of pneumatic separation channels, is presented.

**Key words:** separation channel, cleaning, properties, grain, seeds, loading, channel width, efficiency

### RESEARCH ANALYSIS

Increasing the productivity of grain cleaning separators affects the expenses and cost of post-harvest grain processing and seed preparation. The main technological indicators of separators for grain cleaning and calibration

of seed materials are productivity and quality of separation of their components. These indicators are consistent with each other, but the quality is regulated by the standards of a particular country or international ISO, for example (ISO 605:1977, ISO 7970:2021).

In the technological process of most modern grain and seed cleaning machines, the first stage of material purification is the separation of components according to aerodynamic properties on pneumatic separation channels. After the separation of the components in the pneumatic separation channels, the grain or seed material is separated by size on the sieves. Increasing the productivity of sieves has a number of effective practical solutions, including parallel tiered or sequential cascade placement, the use of innovative sieves with increased screening capacity. Such solutions allow obtaining the maximum possible performance of sieve units. However, despite the increased productivity of sieve units, the constraining factor of the productivity of the entire cleaning machine is the performance of pneumatic separation channels.

Research of processes and methods of grain mixtures cleaning in air flows (Zaika *et. al* 1997; Burkov 1993; Andreev 2005; Kotov *et. al* 2010; Vasylykovskiy *et. al* 2006; Stepanenko 2017; Slipchenko 2012; Kharchenko *et. al* 2021).

Practical use of grain and seed cleaning machines is the following. Scientists conducted research on the process of separation of bulk media by air flow, identified significant factors (Zaika *et. al* 1997; Burkov 1993; Andreev 2005; Kharchenko *et. al* 2021): specific loading of the pneumatic separation channel, uniformity of material distribution along its width; the initial speed and thickness of the layer of grain material particles, the speed and uniformity of the air flow in the

working area.

The initial rate of input and uniformity of distribution of grain material in the PSC, the direction of movement affects the efficiency of separation. By analyzing the works (Kotov *et. al* 2010; Stepanenko 2017), technical means have been established to intensify the distribution of grain material along the width and the optimal parameters have been determined: the rate of introduction of grain material 0.3...0.4 m/s; the angle of inclination of the guide surface is taken to the angle of friction of the grain on the metal 25...35°.

In the work (Abduiev 2007), technical means for ensuring uniformity of the set speed of an air stream in a working zone of the pneumatic separation channel by means of system of blinds are also established.

Existing designs of pneumatic separation channels, taking into account the works (Abduiev 2007; Burkov *et. al* 2002; Yermak 2003), can be classified according to the following features: with open and closed airflow cycles; single-channel, sectional and non-channel; with vertical, inclined, horizontal, annular working channel.

#### MATERIALS AND METHODS

As a result of the analysis of the researches, the designs of pneumatic separation channels are established:

- on the presence of channels: channelless (Fig. 1, a), channel (Fig. 1, b-k);
- on the principle of action: passive (Fig. 1, a-j), active (rotary) (Fig. 1, k);
- by location: single-channel (Fig. 1, b-g, i-k), sectional (Fig. 1, h);
- by the shape of the channel intersection: rectangular (Fig. 1, c, e, h, l), round (Fig. 1, e, f), ring (Fig. 1, i);
- in the direction of the channels: vertical (Fig. 1, b-f, h-j), horizontal (Fig. 1, a), inclined (Fig. 1, g);
- by type of air flow: injection (Fig. 1, a, b, g), suction (Fig. 1, c, e, f, h-k), suction-discharge (Fig. 1, d);
- by type of pneumatic system: machines with open (Fig. 1, a-c, e-k) and closed air flow cycles (Fig. 1, d).

The main disadvantages of the structures noted by researchers are: the lack of uniformity of air flow and distribution of grain material across the width of the channel; significant metal and energy consumption of machines; the size and complexity of structures; low quality cleaning and specific loading.

Also a negative factor, which is characteristic of most designs of pneumatic separation channels, is the supply of grain material in the middle part by means of self-flowing pipes. With a significant width of the pneumatic separation channel (more than 1000 mm) to ensure uniform feed of grain material, it is necessary to use additional switchgear.

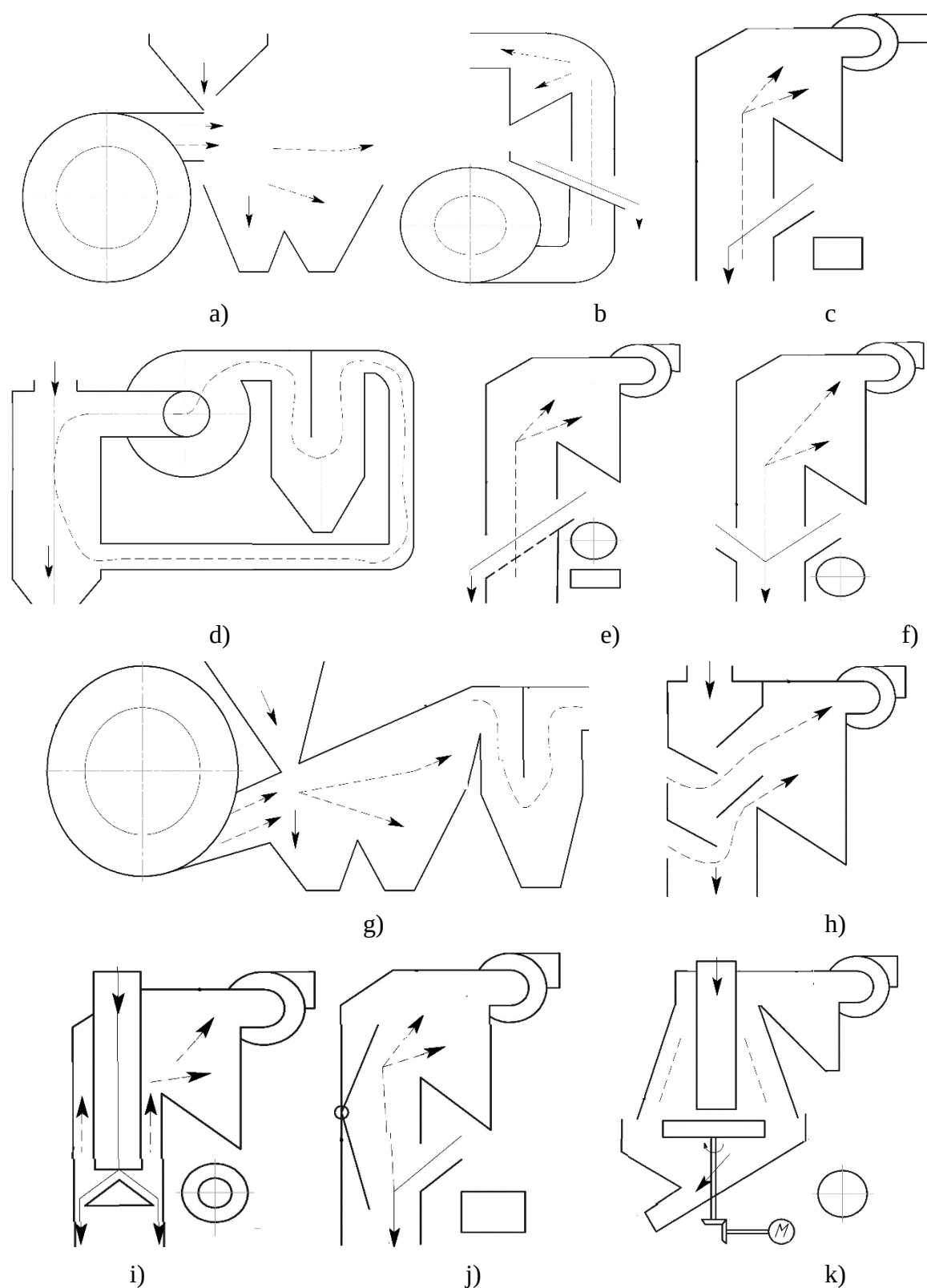
Increasing the width of the channel can be used to increase the productivity of the pneumatic separation channels. This method leads to an increase in the size of the separators and to uneven loading across the width of the channel, which causes a loss of quality of separation of components of grain and seed materials.

The analysis made it possible to systematize and identify promising ways to improve the efficiency of pneumatic separation channels: optimization of technological parameters; preliminary preparation of grain materials and air flow; intensification of distribution of grain materials; using repeated cleaning; combining devices of different types of action.

Thus, a promising way to increase the efficiency of the process of pneumatic separation of grain and seed materials depends on the conditions of their introduction and distribution in the working areas of pneumatic separation channels.

#### THE AIM OF THE WORK

The aim of the work is to determine promising ways to increase the efficiency of pneumatic separation channels of grain and seed cleaning machines and to substantiate the methodology of their research to optimize significant parameters.



**Figure 1.** Schemes of pneumatic separators:

a – injection channelless; b, c – injection and suction channel vertical; d – channel with a closed system; e – suction vertical with an inclined grid; f – suction vertical with perimeter supply; g – injection inclined; h – suction section; i – suction ring; j – suction with a variable working cross-section; k – suction disk rotary

## RESULTS AND DISCUSSION

To study the process of introducing grain materials into the working area of the pneumatic separation channel, the task was to establish an appropriate method.

To determine the speed of grain materials, when they are introduced into the working area, in the transverse and longitudinal sections of the channel must be divided into an equal number of sections. For experimental plots we use a set of rectangular trays.

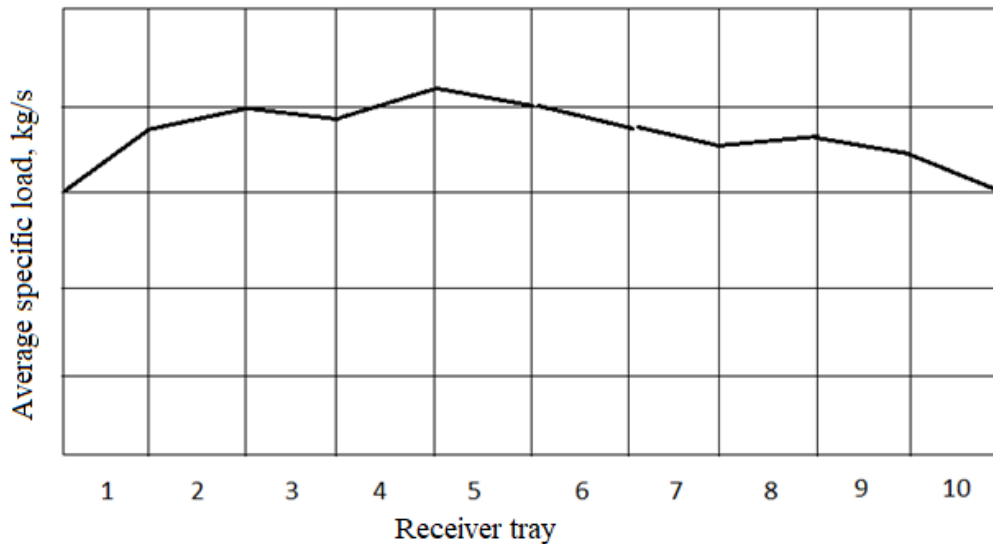
Given the width of most grain and seed cleaning machines 1000 mm, which corresponds to the width (length) of the sieves, we accept 10 trays of 100 mm each.

For research we take a sample of grain material and pour it on the experimental

sloping surface. Then we measure the time of the experiment. Next, we analyze the content of grain (seed) material in the trays-receivers, determine the weight. The experiments must be performed in triplicate and the values are averaged.

When conducting such experiments, attention should be paid to the established mode of operation of the pneumatic separation channel. Therefore, it is necessary to provide means to urgently enter the receiving trays into the working area in the steady state of channel loading. This will ensure the required accuracy in research.

For visual visualization, it is better to present the research results in the form of graphical dependence (Fig. 2).



**Figure 2.** Dependence of grain material distribution on the width of the pneumatic separation channel of the grain cleaning machine

According to the test results, it is necessary to evaluate the efficiency of grain material distribution along the width of the channel.

Sampling time depends on the total specific feed (productivity). Determine the average weight of grain material received on the  $i$ -th section of the width of the pneumatic separation channel during the experiment.

The average weight determines the supply of the  $i$ -th section of the pneumatic separation channel by the expression:

$$Q_i = \frac{q_{avi}}{t}, \text{ kg/s}, \quad (1)$$

where  $q_{av}$  is the average weight of the grain material that fell on the  $i$ -th section of the width of the pneumatic separation channel;

$t$  – duration of repetition of the experiment, sec.

The average supply of grain material in the area of the pneumatic separation channel is determined by the expression:

$$Q_{av} = \frac{\sum_{i=1}^n Q_i}{n}, \text{ kg/s}, \quad (2)$$

where  $\sum Q_i$  – total supply of grain material in the pneumatic separation channel, kg/s;

$n$  – the number of sections (trays) across the width of the pneumatic separation channel.

The numerical indicator of the characteristic of uniformity of distribution of grain material on width of the pneumatic separation channel is found through coefficient of non-uniformity ( $k_n$ ):

$$k_n = \frac{\sigma}{Q_{av}}, \quad (3)$$

where  $\sigma$  – the standard deviation of the average material feed of the material across the width of the channel:

$$\sigma = \sqrt{\frac{\sum_{i=1}^n (Q_i - Q_{av})^2}{n-1}}, \quad (4)$$

$Q_{av}$  – the average feed of the material in the area of the channel width, which is determined by the expression (2).

It should be noted that the determination of the uniformity of the feed depends not only on the design and technological parameters of the channel, but also on the properties of the grain (seed) material.

The design and technological parameters of the channel should include: the angle of inclination of the sloped surface, its length, the amount of grain material supply, the width and thickness of the channel.

The properties of grain (seed) mixtures include: clogging, moisture, density of components and mixtures; coefficients of friction and natural bevel, particle size, porosity of the material.

## CONCLUSIONS

The analysis of the technological processes of grain and seed cleaning machines, the designs of their pneumatic separating channels

made it possible to determine promising ways to increase the efficiency of their work. Among similar methods, it is necessary to highlight the uniform distribution of grain material along the width of the channel.

A methodology for studying the uniformity of distribution of grain or seed material in pneumatic separation channels has been developed, which provides a description of the research, the expression of the main performance indicators, a list of factors affecting its value.

## REFERENCES

- ISO 605:1977 Pulses — Methods of test.  
 ISO 7970:2021 Wheat (*Triticum aestivum* L.) — Specification.  
 Zaika P.M., Slonovskiy N.V. 1997. Study of the trajectory of the movement of seeds during pneumatic separation of seed materials. *Technology of production and design of agricultural machines: Collection of scientific works*. HSAU, Ukraine, P. 142–147.  
 Burkov A.I. 1993. Improving the efficiency of the functioning of pneumatic systems of grain and seed cleaning machines by improving their technological process and the main working bodies: dissertation for the degree of Doctor of Technical Sciences: 05.20.01 / Kirov, 500 p.  
 Andreev V.L. 2005. Increasing the efficiency of cleaning seeds of grain crops in the conditions of the Euro-North-East region by developing and improving technologies and air-sieve machines: dissertation abstract for the degree of Doctor of Technical Sciences: 05.20.01 / Kirov, 39 p.  
 Kotov B.I., Stepanenko S.P., Shvydia V.O. 2010. The results of experimental studies of pneumatic separation of grain in a pneumatic centrifugal separator with an improved experimental disk. *Collection of scientific works of Kirovohrad National Technical University*. Kirovohrad: KNTU, Vol. 23, P. 250 – 257.  
 Vasylovskiy M.I., Vasylovskiy O.M., Leshchenko S.M., O.V.Nesterenko. 2006. Study of the operation of the pneumatic separation channel on a physical model. *Collection of scientific works of Kirovohrad*

- National Technical University. Machinery in agricultural production, industrial engineering, automation. Kirovohrad, Vol.17. P. 44 – 48.*
- Stepanenko S.P. 2017. Research pneumatic gravity separation grain materials. *Mechanization in agriculture, conserving of the resources*. Bulgarian association of mechanization in agriculture. Vol.2. P.54 – 56.
- Slipchenko M.V. 2012. Substantiation of the process parameters and development of a pneumatic separation device for vibrocentrifugal grain separators: dissertation for the degree of Doctor of Technical Sciences: 05.05.11 / KhNTUA. Kharkiv, 273 p.
- Kharchenko S., Borshch Y., Kovalyshyn S., Popardowski E., Kielbasa P. 2021. Modeling of aerodynamic separation of preliminarily stratified grain mixture in vertical pneumatic separation duct. *Applied Sciences* (Switzerland), 11(10), 4383.
- Abduiev M.M. 2007. Substantiation of parameters of the separator with the inclined air channel for separation of grain mixtures: dissertation for the degree of Doctor of Technical Sciences: 05.05.11 / KhNTUA. Kharkiv, 296 p.
- Burkov A.I., Andreev V.L. 2002. Technology for cleaning grain seeds with fractionation on sieves and separate processing by air flow. *Scientific works of VIM*. Vol. 141, ch. 2. P. 103 – 111.
- Yermak V.P. 2003. Improving the method of separating sunflower seeds in air streams: dissertation abstract for the degree of Doctor of Technical Sciences: 05.05.11 / Luhansk National Agrarian University. Luhansk, 18 p.

## IMPROVING THE STABILITY OF THE MOVEMENT OF THE SECTION OF THE COMBINED MACHINE FOR SOIL PREPARATION AND SOWING

Yurii Syromyatnikov, Vitalii Sementsov, Volodimir Sementsov,  
Olexander Nanka, N. Vitsotenko

State Biotechnological University, St. Alchevskih 44, Kharkiv 61000, Ukraine  
e-mail: sementsov1984@ukr.net

**Abstract.** The subject of the study is the process of operation of a combined machine for soil preparation and sowing of sunflower and corn seeds. The technological process of the machine operation with passive rotating flat disks with flanges installed (which properly ensure the movement of soil along the share to the ripping and separating device), a sowing machine, a seed tube, a furrow former, a rotor, a separating grate, a parallelogram mechanism, a spring, a share are described. The dynamic prerequisites for increasing the uniformity of the depth of furrow formation and seed placement in depth in the soil are considered. The values of the length of the links of the parallelogram mechanism, the initial angle of their installation and the stiffness of the spring, the deviations of the section of the combined machine from the specified depth of the plowshare are determined. It is proved that with an increase in the length of the levers of the parallelogram mechanism, the maximum deviations of the section increase. An increase in the initial tilt angle of the levers of the parallelogram mechanism causes an increase in the maximum deviations. As the spring stiffness increases, the maximum deflections decrease. The relevance of the study lies in ensuring the stability of copying the soil surface by the working bodies of the combined machine with the depth of seed placement unchanged along the entire length of the movement, which will make it possible to increase the speed of movement and the width of the unit. The target group of consumers of information in the article are designers, specialists involved in the development of tillage machines.

**Key words:** combined machine, soil redistribution, rotor, furrow former, frame, support and press wheel, sowing, separating grid, ploughshare, seed placement.

### ANALYSIS OF RECENT RESEARCH

The development of sowing equipment has long been aimed primarily at increasing productivity, that is, at increasing working speeds, working widths, and tractor power, and in this regard, significant progress has been made.

The technology based on the use of combined machines has a positive effect on reducing energy costs by reducing the number and depth of processing, combining mechanical operations in one unit – processing, sowing (Rahmati *et. al* 2020; Great Plains / Product catalog. 1994; López *et. al* 2019).

Therefore, such combined machines, which in one pass provide the preparation of the seed bed and sowing, are usually called direct sowing seeders (Syromyatnikov 2021; Pisarev O. *et al.* 2019).

There are three types of direct drills:

- strip loosening of the soil with a wavy disk;
- undercutting type with seed distribution under the lancet share;
- combined, combining working bodies of the undercutting type and coulter systems.

The evaluation criterion in this case is the indicator of uniform distribution of seeds in depth (Nanka et al. 2019; Gao et al. 2020).

They are used for sowing grain crops on cultivated and uncultivated soils with preserved stubble.

Direct sowing seeders with undercutting paws, or seeders with paw coulters are used for sowing seeds of grain crops on stubble or on insufficiently cultivated soil (Syromyatnikov et al. 2021; Rogovskii et al. 2021). Such a coulter performs several operations simultaneously - loosening the soil, removing weeds, sowing seeds.



The advantages of direct sowing drills are that they loosen the soil only in the seed placement zone and create the necessary seed-to-soil contact. Direct sowing seeders in Western Europe, which has light soils, provide soil preparation according to "zero" technology. In the conditions of the USA, Canada and the Forest-Steppe of Ukraine on soils of medium and heavy mechanical composition, as practice has shown, the "zero" technology does not provide the necessary contact between seeds and the solid phase of the soil (Or D. *et. al* 2021; Bartley 2019; Feurdean *et. al* 2021). Therefore, in our conditions, direct sowing seeders, which provide tillage in the seed bed, have a perspective.

Direct sowing seeders with flat-cutting shares provide the most promising way of sowing - broadcast. At the same time, weeds are removed across the entire width of the seeder, and the presence of seed bins in them helps to increase their productivity (Bogus *et. al* 2019; Jiang *et. al* 2021).

The disadvantages of such machines include the fact that they can provide the required agricultural technology for the cultivation of grain crops and the uniformity of seed placement in depth only on leveled fields,

where plowing is not used in the main sowing treatment system. In addition, they cannot work in the presence of a large amount of crop residues and weeds (Pastukhov *et. al* 2020; Radnaev *et. al* 2022).

With the increase in the level of intensification of production and the development of a biotechnological approach to the cultivation of grain crops, the issues of technical support for high-quality sowing came to the fore in sowing technology: optimal placement of seeds in area and depth, creation of a dense seed bed. To achieve such conditions for sowing, and most importantly, to create favorable conditions for the growth and further development of plants is possible only with high-quality pre-sowing tillage and sowing with combined aggregates.

#### FORMULATION OF THE PROBLEM

Known developed by V.F. Pashchenko combined machine for soil preparation and sowing of sunflower and corn seeds.

The general view of the combined machine for pre-sowing soil preparation and sowing by fractional redistribution of soil over the seeds previously laid in the furrow is shown in Figure 1



**Figure 1.** Combined seedbed and seedbed machine

The machine consists of a frame, six working sections, an ejector device, support wheels and markers. The working section includes a frame, a parallelogram mechanism, a plowshare with a furrow former, guide discs, a separating grid, a rotor, a sowing unit of the SUPN-8 seeder, a box for seeds and a seed duct.

The working process of the machine proceeds as follows (Pashchenko *et. al* 2017; Pashchenko *et. al* 2019). The soil, trimmed with a plowshare, is fed to the ripping and separating device with the help of guide discs. At the same time, the seeds from the sowing unit are fed through the seed pipeline into the wedge-shaped soil furrow formed by the furrower. The rotor pinches soil clods between the knives and the separating grate, crushes and transports them (Pashchenko *et. al* 2018; Pashchenko *et. al* 2019).

Small soil particles pass through the gaps of the separating grid and cover the seeds laid in the furrow. When tedding the soil along the separating grid, large particles are pushed to the surface, while small ones fall down (Pashchenko *et. al* 2019).

An important factor providing an increase in the yield of agricultural crops is the uniform distribution of seeds over the depth in the soil (Kalabushev *et. al* 2019; Nielsen *et. al* 2018).

Therefore, along with other technical and technological requirements for tillage and sowing machines, the requirement regarding the uniformity of the depth of tillage and seed placement is important.

and

reduce fuel consumption for seedbed preparation by 20–40% (Syromyatnikov *et. al* 2021).

Aggregates based on a combination of single-operation tools, although they have some advantages, do not justify themselves because of their bulkiness, instability of movement in a straight direction and inconsistency in their working width. Sowing combines, with the working bodies of the seeder and tillage implements installed on the same frame, made in the form of paws or discs, are less bulky.

In this case, such requirements relate to the depth of the formation of the groove in which the seeds of the plants must be placed.

## ANALYSIS OF RESEARCHES AND PUBLICATIONS

Modern science increasingly recommends the use of a soil-protective tillage system for production by reducing the depth of cultivation, the number of mechanical treatments, or by combining a number of technological operations. This technology achieves the preservation of the soil structure, eliminates excessive soil compaction, and increases its resistance to erosion processes.

There are many scientific justifications about the possibility of completely abandoning a large number of mechanical tillage.

The ideas of reducing the number of operations performed in agriculture have long been put forward by scientists. More D.I. Mendelev wrote that "... regarding the quality of plowing, many are mistaken, thinking that the more times to plow, the better."

The priority direction is increasingly gaining the use of combined tillage machines and aggregates (Syromyatnikov 2021). The latter have high productivity, are cheap to use, do not violate agri-technical requirements and help to reduce the time of technological operations.

The use of these machines in production makes it possible to combine from two to six operations

Reducing the metal and energy consumption of combined machines with active working bodies can be obtained by strip tillage. Such machines are created on the basis of row cutters and seeders.

Less energy-intensive and more reliable in operation are combined tillage machines with active-passive working bodies. These include the Dokuchaev PRSM-5 soil-cultivating ripping-separating machine (stratifier) (Syromyatnikov *et. al* 2022).

Production tests of the proposed types of combined machines show that the best performance in work is given by the type of



Such a structural combination of working bodies with frames of the section and the machine was carried out in order to ensure both the fractional separation of the soil and the uniform distribution of seeds in depth. In this case, the task becomes to ensure the minimum possible deviation of the position of the seeds relative to the track of the support-packing wheel.

The solution of the problem is carried out by selecting the stiffness of the spring 7, the dimensions of the links of the parallelogram mechanism 8 and the initial angle of their inclination to the horizontal plane  $\varphi_0$ .

We refer the system under consideration to the fixed Cartesian coordinates  $x$  and  $z$ . The direction of rotation of the links of the parallelogram mechanism clockwise is assumed to be positive.

To solve the problem in the first approximation, it can be assumed that with the floating position of the spool of the distributor of the tractor hydraulic system in the steady-state operation mode ( $V_M = \text{const}$ ),

the frame of the combined machine, copying the sinusoidal surface of the field, moves according to the law

$$\begin{aligned} x_p &= V_M t, \\ z_p &= \mu \cdot \sin \lambda \cdot x_p - a_5, \end{aligned} \quad (1)$$

where  $x_p$ ,  $z_p$  are the coordinates of the center of mass of the machine frame and its supporting wheels, m;  $t$  – time, s;  $\mu$ ,  $\lambda$  are constant coefficients depending on the field topography;  $a_5$  – distance from the axle  $x$  to the center of mass of the machine frame and its support wheels, m.

The soil will be considered as an elastic medium, and the rim of the support-packing wheel 6 will be considered non-deformable.

We will also assume that the forces applied to the disks, the plowshare and the rotor are reduced to some resultant forces that have a constant value, as for the reactions applied to the support-press wheel 6, then, based on the available data, we can take

$$\begin{aligned} R_{KX} &= f \cdot C_{II} \cdot \Delta_{II}, \\ R_{KZ} &= C_{II} \cdot \Delta_{II}, \end{aligned}$$

where  $R_{KX}$ ,  $R_{KZ}$  are the vertical and horizontal components of the forces applied to the wheel, N;  $C_{II}$  – soil stiffness, N/m;  $f$  – rolling coefficient;  $\Delta_{II}$  – magnitude of soil deformation, m.

Let us determine the magnitude of soil deformation through the angle of rotation of the links of the parallelogram mechanism. Then we get

$$\Delta_{II} + z_C - z_p = l [\sin(\varphi_0 + \varphi) - \sin \varphi_0] + a_5, \quad (2)$$

where  $z_C$  is the coordinate of the center of mass of the section, m;  $l$  – the length of the lever AB, m.

$$\begin{aligned} z_C &= \mu \cdot \sin \lambda (V_M t - V_M t_1), \\ t_1 &= \frac{l \cos(\varphi_0 + \varphi) + a_6}{V_M}, \end{aligned}$$

where  $a_6$  is the distance from the O axis of the wheel 6 to the hinge B of the link of the parallelogram mechanism in the horizontal plane, m.

Then

$$z_C = \mu \cdot \sin \lambda (V_M t - l \cos(\varphi_0 + \varphi) - a_6).$$

After substituting the values  $z_C$  and  $z_p$  into equation (2), we obtain

$$\Delta_{II} = l [\sin(\varphi_0 + \varphi) - \sin \varphi_0] + \mu \cdot \sin \lambda \cdot V_M \cdot t - \mu \cdot \sin \lambda (V_M t - l \cos(\varphi_0 + \varphi) - a_6). \quad (3)$$

Considering that soil deformation occurs only when the section is displaced in the positive  $z$  direction, we obtain

$$\Delta_{II} = \frac{l[\sin(\varphi_0 + \varphi) - \sin \varphi_0] + \mu \cdot \sin \lambda \cdot V_M \cdot t - \mu \cdot \sin \lambda (V_M t - l \cos(\varphi_0 + \varphi) - a_6)}{2} + \left| \frac{l[\sin(\varphi_0 + \varphi) - \sin \varphi_0] + \mu \cdot \sin \lambda \cdot V_M \cdot t - \mu \cdot \sin \lambda (V_M t - l \cos(\varphi_0 + \varphi) - a_6)}{2} \right|.$$

Then

$$R_{KX} = f \cdot C_{II} \left\{ \frac{l[\sin(\varphi_0 + \varphi) - \sin \varphi_0] + \mu \cdot \sin \lambda \cdot V_M \cdot t - \mu \cdot \sin \lambda (V_M t - l \cos(\varphi_0 + \varphi) - a_6)}{2} + \left| \frac{l[\sin(\varphi_0 + \varphi) - \sin \varphi_0] + \mu \cdot \sin \lambda \cdot V_M \cdot t - \mu \cdot \sin \lambda (V_M t - l \cos(\varphi_0 + \varphi) - a_6)}{2} \right| \right\} \quad (4)$$

$$R_{KZ} = C_{II} \left\{ \frac{l[\sin(\varphi_0 + \varphi) - \sin \varphi_0] + \mu \cdot \sin \lambda \cdot V_M \cdot t - \mu \cdot \sin \lambda (V_M t - l \cos(\varphi_0 + \varphi) - a_6)}{2} + \left| \frac{l[\sin(\varphi_0 + \varphi) - \sin \varphi_0] + \mu \cdot \sin \lambda \cdot V_M \cdot t - \mu \cdot \sin \lambda (V_M t - l \cos(\varphi_0 + \varphi) - a_6)}{2} \right| \right\} \quad (5)$$

As an independent (generalized) coordinate of the system under consideration, it is convenient to take the angle of rotation of the link of the four-link parallelogram mechanism AB relative to the hinge A. Then the differential equation of motion of the section will be written as

$$\frac{d\partial T}{dt\partial\varphi} - \frac{\partial T}{\partial\varphi} = Q_\varphi, \quad (6)$$

where  $T$  is the kinetic energy of the system, Nm;  $Q_\varphi$  – generalized force, Nm.

Before writing the expression for the kinetic energy of the system, we note that in the problem being solved, if the rotation of disks 2, rotor 5, wheel 6 is assumed to be uniform and the forces of resistance to their rotational motion are constant, then there is no need to formulate the equations of motion of the latter. With this in mind, the expression for the kinetic energy of the system can be written as

$$T = \frac{1}{2} M_C (\dot{x}_C^2 + \dot{z}_C^2), \quad (7)$$

where  $M_C$  is the mass of the section, kg;  $x_C$ ,  $z_C$  are the coordinates of the center of mass of the section, m.

Expressing  $x_C$  and  $z_C$  from the geometric conditions in terms of the values  $x_p$  and  $z_p$ , differentiating them with respect to time and substituting into equation (7), we obtain

$$T = \frac{1}{2} M_C \left[ V_M^2 + 2V_M l \dot{\varphi} \sin(\varphi_0 + \varphi) + l^2 \dot{\varphi}^2 \sin^2(\varphi_0 + \varphi) + \mu^2 \lambda^2 V_M^2 \cos^2 \lambda V_M t + 2\mu \lambda V_M \cos \lambda V_M l \dot{\varphi} \cos(\varphi_0 + \varphi) + l^2 \dot{\varphi}^2 \cos^2(\varphi_0 + \varphi) \right]. \quad (8)$$

Because

$$\frac{\partial T}{\partial \dot{\varphi}} = M_C l [V_M \sin(\varphi_0 + \varphi) + l \dot{\varphi} + \mu \lambda V_M \cos \lambda V_M t \cos(\varphi_0 + \varphi)],$$

$$\frac{d\partial T}{dT\partial\dot{\varphi}} = M_C l \left[ V_M \dot{\varphi} \cos(\varphi_0 + \varphi) + l\ddot{\varphi} - \mu\lambda^2 V_M^2 \sin \lambda V_M t \cos(\varphi_0 + \varphi) - \mu\lambda V_M \dot{\varphi} \cos \lambda V_M t \sin(\varphi_0 + \varphi) \right]$$

$$\frac{\partial T}{\partial \varphi} = M_C l \left[ V_M \dot{\varphi} \cos(\varphi_0 + \varphi) - \mu\lambda V_M \dot{\varphi} \cos \lambda V_M t \sin(\varphi_0 + \varphi) \right],$$

we get

$$\frac{d\partial T}{dT\partial\ddot{\varphi}} - \frac{\partial T}{\partial \varphi} = M_C l \left[ l\ddot{\varphi} - \mu\lambda^2 V_M^2 \sin \lambda V_M t \cos(\varphi_0 + \varphi) \right]. \quad (9)$$

To determine the generalized forces, we use the principle of possible displacements. Then, if we bring all the reactive forces to the hinge B of the link of the parallelogram mechanism 8, using the theorem on the parallel transfer of forces, we obtain

$$\partial A_\varphi = \left[ \begin{aligned} &R_X l \sin(\varphi_0 + \varphi) + R_Z l \cos(\varphi_0 + \varphi) + C_{HP} (h - z_C) l \cos(\varphi_0 + \varphi) - \\ &- R_{KX} l \sin(\varphi_0 + \varphi) - R_{KZ} l \cos(\varphi_0 + \varphi) \end{aligned} \right] d\varphi,$$

where  $R_X$ ,  $R_Z$  are the horizontal and vertical components of the resultant forces applied to the disks, the rotor, the plowshare, the separating grate and the weight of the section, N;  $C_{HP}$  – spring stiffness, N/m;  $h$  – spring pretension, m;

$$R_X = R_{PX} - R_{DX} - R_{LX} - R_{FX},$$

$$R_Z = M_{CG} - R_{LZ} - R_{DZ} - R_{PZ},$$

where  $R_{LX}$ ,  $R_{DX}$ ,  $R_{PX}$ ,  $R_{LZ}$ ,  $R_{DZ}$ ,  $R_{PZ}$  are the horizontal and vertical components of the resultant reactive forces applied to the share, disks and rotor;  $R_{FX}$  is the force of resistance to friction of the soil against the separating grid, N.

Because

$$z_C = l \left[ \sin(\varphi_0 + \varphi) - \sin \varphi_0 \right]$$

then, taking into account equations (4), (5) and (9), we obtain

$$\begin{aligned} Q_\varphi = & R_X l \sin(\varphi_0 + \varphi) + R_Z l \cos(\varphi_0 + \varphi) + C_{HP} l \cos(\varphi_0 + \varphi) \times \\ & \times \left\{ h - l \left[ \sin(\varphi_0 + \varphi) - \sin \varphi_0 \right] \right\} - C_{HP} l \left[ \cos(\varphi_0 + \varphi) + f \sin(\varphi_0 + \varphi) \right] \times \\ & \times \left\{ \frac{l \left[ \sin(\varphi_0 + \varphi) - \sin \varphi_0 \right] + \mu \cdot \sin \lambda \cdot V_M \cdot t - \mu \cdot \sin \lambda (V_M t - l \cos(\varphi_0 + \varphi) - a_6)}{2} + \right. \\ & \left. \times \left\{ \frac{l \left[ \sin(\varphi_0 + \varphi) - \sin \varphi_0 \right] + \mu \cdot \sin \lambda \cdot V_M \cdot t - \mu \cdot \sin \lambda (V_M t - l \cos(\varphi_0 + \varphi) - a_6)}{2} \right\} \right\} \end{aligned} \quad (10)$$

Substituting expressions (8) and (10) into equation (6), we obtain a calculation model for the functioning of the section of the combined machine for planting seeds and the fractional distribution of soil over the depth of the sowing layer

$$\begin{aligned} \ddot{\varphi} = & M_C l \left[ R_X l \sin(\varphi_0 + \varphi) + R_Z l \cos(\varphi_0 + \varphi) \right] + \frac{C_{HP} \cos(\varphi_0 + \varphi)}{M_C l} \times \\ & \times \left\{ h - l \left[ \sin(\varphi_0 + \varphi) - \sin \varphi_0 \right] \right\} - \frac{C_{HP} \left[ f \sin(\varphi_0 + \varphi) + \cos(\varphi_0 + \varphi) \right]}{M_C l} \times \\ & \times \left\{ \frac{l \left[ \sin(\varphi_0 + \varphi) - \sin \varphi_0 \right] + \mu \cdot \sin \lambda \cdot V_M \cdot t - \mu \cdot \sin \lambda (V_M t - l \cos(\varphi_0 + \varphi) - a_6)}{2} + \right. \\ & \left. \times \left\{ \frac{l \left[ \sin(\varphi_0 + \varphi) - \sin \varphi_0 \right] + \mu \cdot \sin \lambda \cdot V_M \cdot t - \mu \cdot \sin \lambda (V_M t - l \cos(\varphi_0 + \varphi) - a_6)}{2} \right\} \right\} + \\ & + \frac{\mu \lambda^2 V_M^2 \sin \lambda V_M t \cos(\varphi_0 + \varphi)}{l} \end{aligned} \quad (11)$$

The differential equation is solved by Runge-Kutt method. Then the obtained value of the angle was substituted into equation (3) and the values of the deviation of the combined machine section from the specified depth of tillage and seeding were found.

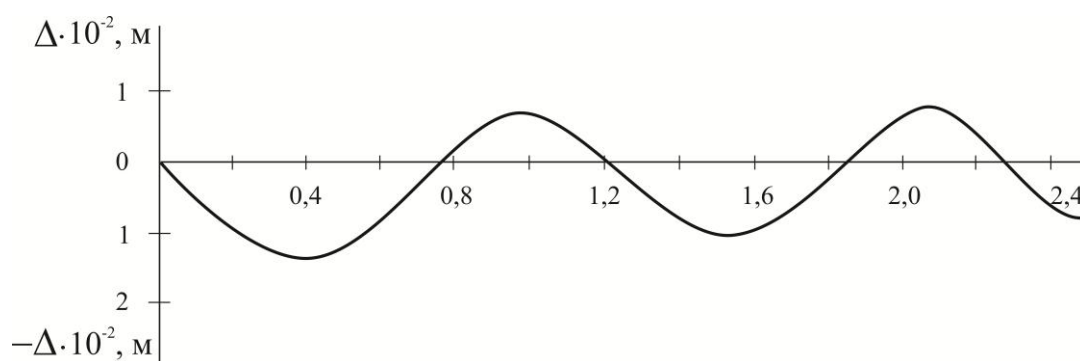
For calculation it was accepted:  
 $R_x = -700$  N,  $R_z = -40$  N,  $h = 0,08$  m,  
of

the combined machine section from the given depth of the plowshare were determined. The character of section vibrations is shown in fig. 3. The

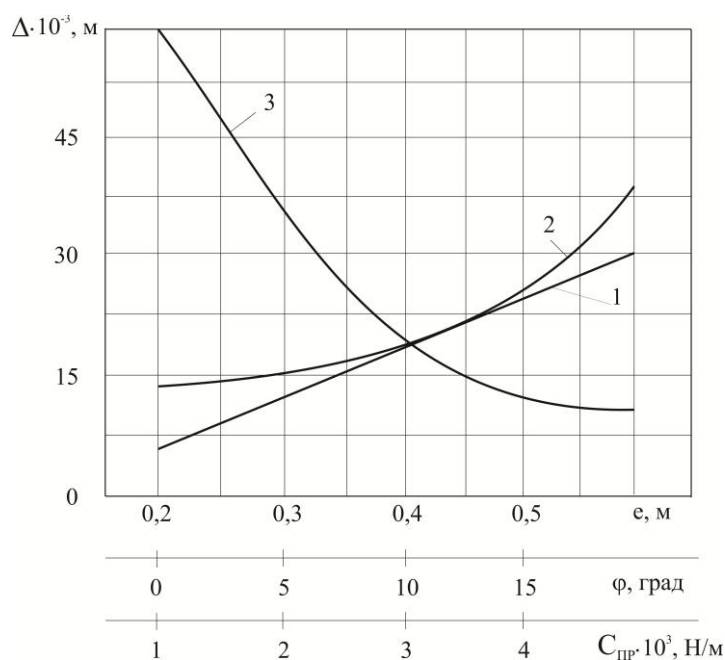
$M_C = 88$  kg,  $C_{II} = 80000$  N/m,  $f = 0,02$ ,  
 $\mu = 0,04$ ,  $\lambda = 0,5$ ,  $V_M = 2,2$  m/s.

The values of the length of the links of the parallelogram mechanism, the initial angle  $\varphi_0$  of their installation and the stiffness of the spring  $C_{II}$  were changed and various deviations

dependences of the numerical values of the maximum deviations of the combined machine section are shown in fig. 4.



**Figure 3.** The nature of the deviation of the combined machine section from the specified depth of tillage



**Figure 4.** Dependence of the maximum deviation of the combined machine section relative to the specified processing depth

The data of the graph (Fig. 4) indicate that with an increase in the length of to

0.4 m, the maximum deviations of the section increase by 3 times; with an increase in length from 0.2 to 0.6 m - five times. An increase in the initial tilt angle of the levers of the parallelogram mechanism from 0 to 100 causes an increase in maximum deviations by 28.5%, and from 0 to 200 - by 185%. By increasing the spring rate from 1000 to 3000 N/m, the maximum deflections are reduced by 50%, and from 1000 to 8000 N/m by 100%.

### CONCLUSIONS

To increase the stability of the movement of the combined machine section, the length of the links of the parallelogram mechanism and the angle of their inclination to the horizontal plane must be chosen as small as possible, and the spring stiffness should be close to 8000 N/m.

### REFERENCES

- Rahmati M. et al. 2020. Changes in soil organic carbon fractions and residence time five years after implementing conventional and conservation tillage practices. *Soil and Tillage Research*, T. 200, P. 104632.
- Great Plains / Product catalog. 1994. Great Plains Manufacturing, Inc: Printed U.S.A., BAC 13599/10/94. 68 p.
- López F. J., Pastrana P., Casquero P. A. 2019. Soil physical properties and crop response in direct seeding of spring barley as affected by wheat straw level. *Journal of Soil and Water Conservation*, T. 74, №. 1, P. 51–58.
- Syromyatnikov Yu. N. 2021. Influence of direct sowing methods on the growth, development and productivity of spring barley grown under the conditions of the north-eastern part of Ukraine. *Scientific journal "Izvestiya of Timiryazev Agricultural Academy"*, №. 3, P. 27–39. <https://doi.org/10.26897/0021-342X-2021-3-27-39>.
- the levers of the parallelogram mechanism from 0.2
- Pisarev O. et al. 2019. Experimental studies of combined coulter for direct strip sowing of seeds. *MATEC Web of Conferences*. – EDP Sciences, T. 298, P. 00140.
- Nanka A. et al. 2019. Improving the efficiency of a sowing technology based on the improved structural parameters for colters. *Eastern-European journal of enterprise technologies*, №. 4 (1), P. 33–45.
- Gao X. et al. 2020. Numerical simulation of particle motion characteristics in quantitative seed feeding system. *Powder Technology*, T. 367, P. 643–658.
- Syromyatnikov Y. N. et al. 2021. Improving stability of movement of machine section for soil preparation and seeding. *Journal of Physics: Conference Series. IOP Publishing*, T. 2094, №. 4, P. 042027.
- Rogovskii I. L. et al. 2021. Technological effectiveness of formation of planting furrow by working body of passive type of orchard planting machine. *IOP Conference Series: Earth and Environmental Science. IOP Publishing*, T. 839, №.5, P. 052055.
- Or D., Keller T., Schlesinger W. H. 2021. Natural and managed soil structure: On the fragile scaffolding for soil functioning. *Soil and Tillage Research*, T. 208, P. 104912.
- Bartley G. 2019. Wheat (*Triticum aestivum*) residue management before growing soybean (*Glycine max*) in Manitoba : diss.
- Feurdean A. et al. 2021. The transformation of the forest steppe in the lower Danube Plain of southeastern Europe: 6000 years of vegetation and land use dynamics. *Biogeosciences*, T. 18. №. 3, P. 1081 – 1103.
- Bogus A. E., Kuzmenko A. D. 2019. Substantiation of the technological scheme of pneumatic grain seeder of subsurface dense sowing. *E3S Web of Conferences*. – EDP Sciences, T. 126, P. 00040.
- Jiang S. et al. 2021. Brief Review of Minimum or No-Till Seeders in China. *AgriEngineering*, T. 3. №. 3, P. 605 – 621.



- Pastukhov V. et al. 2020. Study of seed agitation in the fluid of a hydropneumatic precision seeder. *Eastern-european journal of enterprise technologies*, T. 5. №. 1-107, P. 36 – 43.
- Radnaev D. N. et al. 2022. The coulter effect on the spring wheat yield at different row spacing and seeding rate. *IOP Conference Series: Earth and Environmental Science*. – IOP Publishing, T. 949, №. 1, P. 012069.
- Pashchenko V. F., et al. 2017. Substantiation of the parameters of a tillage machine for energy saving soil treatment technology. *Vestnik of the Sumy National Agrarian University Series: Mechanization and automation of virobnych processes*, №. 10, P. 36-40.
- Pashchenko V. F. et al. 2019. Qualitative performance indicators of a ripping-and-separating machine for soil cultivation in the growth of sugar beet. *Vegetable and Melon Growing*, №. 65, P. 39–49.
- Pashchenko V. F. et al. 2018. Soil-cultivating setting a flexible working organ to control of weeds growth. *Vegetable and Melon Growing*, T. 64, P. 33-43.
- Pashchenko V. F. et al. 2019. The influence of local loosening of the soil on soybean productivity. *Tractors and Agricultural Machinery*, №. 5, P. 79 – 86.
- Pashchenko V. F. et al. 2019. The transporting ability of the rotor of the soil-cultivating loosening and separating vehicle. *Tractors and Agricultural Machinery*, №. 2, P. 67 – 74.
- Kalabushev A. N., Laryushin N. P., Shumaev V.V. 2019. Theoretical calculation of certain parameters of a combined coulter. *Volga Region Farmland*, №. 1, P. 94 – 97.
- Nielsen S. K. et al. 2018. Seed drill depth control system for precision seeding. *Computers and electronics in Agriculture*, T. 144, P. 174 – 180.
- Syromyatnikov Y. N. 2021. Justification of the parameters of the ripper of the tillage machine of the stratifier. *Engineering Technologies and Systems*, T. 31, №. 2, P. 257 – 273. <https://doi.org/10.15507/2658-4123.031.202102.257-273>.
- Syromyatnikov Y. et al. 2021. Productivity of tillage loosening and separating machines in an aggregate with tractors of various capacities. *Journal of Terramechanics*, T. 98, P. 1-6.
- Syromyatnikov Y. et al. 2022. Field tests of the experimental installation for soil processing. *Journal of Terramechanics*, T. 100, P. 81 – 86.
- Syromyatnikov Y. N. et al. 2021. Cultivator points of the rotary tillage loosening and separating machine of the stratifier. *Journal of Physics: Conference Series*. – IOP Publishing, T. 2094, №. 4, P. 042024.
- Matin M. A. et al. 2021. Optimal design and setting of rotary strip-tiller blades to intensify dry season cropping in Asian wet clay soil conditions. *Soil and Tillage Research*, T. 207, P. 104854.
- Starovoytov S. I., Akhalaya B. KH., Mironova A. V. 2019. Konstruktivnyye osobennosti rabochikh organov dlya uplotneniya i vyравnivaniya poverkhnosti pochvy. *Elektrotekhnologii i elektrooborudovaniye v APK*, 2019. №. 4, P. 51 –56.
- Parkhomenko G. G., Kambulov S. I., Pakhomov V. I. 2021. Agrotekhnicheskiye i energeticheskiye pokazateli pochvoobrabatyvayushchikh rabochikh organov. *Inzhenernyye tekhnologii i sistemy*, T. 31, №. 1.

## AGRICULTURAL TRANSPORT – THE TYPE AND STRUCTURE FORMATION OF THE WHEELED VEHICLES FLEET

Krainyk L. V., Syvulka P. M., Khudaverdian H. A., Gabriel Y. I.

*Lviv National Agrarian University*

*Volodymyra Velykoho Street, 1, Dublyany, Zhovkva district, Lviv region, Ukraine*

*e-mail: [l.kraynyk@gmail.com](mailto:l.kraynyk@gmail.com)*

Technological transport in the agricultural sector (domestic transportation from the "field – warehouses") is economically significantly different from the usual road freight transport. First of all, this is due to the specifics of traffic conditions (a significant share of which is dominant in domestic traffic on agricultural holdings) is off-road and field roads. Secondly, the uneven seasonal distribution of traffic volumes during the year is pronounced. Thirdly, the coexistence in domestic transportation of both automotive equipment and wheeled tractors with trailers. The collapse of the previous Soviet era, the collective farm system of the agrarian economy and the gradual formation of large agricultural holdings on the one hand and large farms on the other, led to the problem of appropriate formation of a rational type of agricultural machinery, which obviously has its own specifics primarily in terms of agri-environment, including the structures themselves in comparison with the usual freight transport for paved roads.

**Key words:** agricultural transport, off-roads, trucks and tractors with trailers, type, agro-ecology.

**Objective** to conduct a comparative analysis of research results in the EU on the effectiveness of the use of heavy agricultural tractors and trucks with trailers for technological agricultural transportation and to assess the formation of a rational type of this equipment in Ukraine.

Traffic conditions and the nature of transportation (and ultimately the vast majority of the range of goods themselves) of wheeled transport in the agricultural sector of the economy differ significantly from the usual trucking by roads of I and II categories. This applies to: a significant, in fact, the dominant share of roads are dirt and off-road (agricultural land – part of the transport process in crop production, including in the

spring and autumn with wet soils), which leads to special requirements for the passability of wheeled vehicles, one side and the so-called agri-environmental structures (ie the impact of compaction of the top layer of soil by the wheels of machines during the movement on the fertility of agricultural land). This imposes special requirements on wheeled vehicles (not only trucks, but also wheeled tractors with trailers) in terms of allowable specific pressure on the ground (support surface), which is obviously fundamentally different from the usual weight of 12 tons per axle for trucks on roads of I and II categories with asphalt-concrete pavement. Let us consider the inevitable participation of wheeled vehicles in the technological processes of agricultural production in the fields, where agri-environmental restrictions on the allowable pressure in the area of contact of tires with the ground, according to legislation (Ignatov, 1978), especially during spring work with typically the highest moisture content in the upper layers 50–100kPa, and 60–140kPa in summer and autumn (depending on the degree of humidity). That is, according to the results of research (Elisaev *et. al* 1984), the domestic wheeled tractor T-150K with a gross weight of 8.4 t + 1.7 t load on the coupling device from a two-axle trailer 1PTS-9 with a gross weight of 14.9 t (–1.7 t) only 24–26% of agricultural lands of Ukraine in the spring-autumn periods of intensive agriculture are operated without violating agri-environmental requirements. The use of a truck with a similar load of 10 tons (gross weight 18.4 tons), even with atypical for this class wheel scheme type Kamaz-53212 due to a significant reduction in the area of contact of tires with the bearing surface (tires 260–508R compared to 23.1 R26 in T-150K) does not meet the regulatory requirements of agro-ecology (Elisaev *et. al* 1984). This is especially true of the currently

dominant in this class total weight of 18 tons of two-axle trucks with a real load on the rear axle of about 12 tons. The problem of devastating agro-ecological impact of increasing specific pressure on the soil in light of the growing productivity of agricultural machinery, and hence the capacity and weight of both trucks and tractors, similarly previously recognized as decisive for reducing yields and degradation of agricultural land in the EU (Gisi *et. al* 1997), where relevant legislation has already been adopted and is being adopted to prevent the degradation of agricultural land.

Crawler tractors with significantly lower specific pressure on the ground at a comparable gross weight, in domestic transport works are not competitive with wheeled vehicles due to 2–3 times lower technical speeds, 3–5 times higher linear fuel consumption are practically not used. Wheeled tractors, on the other hand, are widely used, but the impact on soil degradation depends significantly on the total weight of the tractor (traction class).

#### ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Significant changes in the type and structure of the fleet of tractors and cars in agricultural production over the past 20–30 years compared to the practice of 1970–80 led to the dominance of light wheeled vehicles in family and small farms and heavy in agricultural holdings and large farms. In fact, heavy machinery used on most agricultural lands is critical to agri-environmental conditions (despite its advantages in productivity and energy consumption). This problem, however, is practically not covered in domestic studies, but enough attention has been paid in foreign studies, including recently in Russia (Gisi *et. al* 1997). It should be noted the emergence of domestic research on the tractor fleet in terms of agro-ecology (Bernhardt *et. al* 2014).

The average volume of domestic traffic per 1 ha of arable land is from 3 to 12 tons (mineral and organic fertilizers, seeds, crops) – depending on the type of crop and agricultural technology.

When using modern intensive agricultural technologies, which is typical for large farms – agricultural holdings, the number of wheeled

vehicles in the field on the width of cultivation or harvesting of other machine-tractor units, depending on the type of crop, is according to (Bernhardt *et. al* 2014) from 2 to 6 passes and the total number of passes of wheeled vehicles in the field from 5 to 15, ie the total area of traces of 25–50% of the cultivated field, which due to compaction and degradation of topsoil in turn causes a decrease in yield by 20–30% (for example grain cultures).

The main volume of transport work in agriculture is accounted for by domestic transportation, ie dirt roads and cultivated fields (according to (Bernhardt *et. al* 2014) up to 75–80% of the total volume of traffic – in the end the above 3–12 tons of fertilizers, seeds, crops for each hectare of arable land (Völkl *et. al* 2011). The ratio in the performance of these works by trucks and tractors with trailers during the production period was almost in close proportions of 60:40 (Völkl *et. al* 2011), but it should be noted that in 1970–80 in the agricultural sector of the USSR was dominated by 2–3 times lighter in terms of operating weight of tractors and trucks (MTZ 80 – 3.6–4t and trailer 4–6t, GAZ 52/53 – 5.2–7.4t), which lost in productivity to the next (and already available at that time in USA and Western Europe) generation of agricultural wheeled machines. However, it should be noted that already in the 1980 s in the USSR began mass production of the next (in relation to MTZ and GAZ) generation of more energy-efficient agricultural machinery tractors T-150 and T-150K (traction class 3.0t compared to 1.4t in MTZ) and specialized trucks HAZ 4540 scheme 4x4 (gross weight 12.26 tons and a load of 5.5 tons compared to GAZ with a load of 1.5–3.5 tons) and three-axle URAL 377 scheme 6x4 (load 7.5 tons and a gross weight of 15 tons), which were equipped with two-axle trailers with a load capacity of 5 and 7 tons, respectively (Ipatov, 2008).

In fact, it is possible to state the emergence of already specialized trucks (actually dump trucks with 3-way unloading of the body, which is 55–65%) trucks KAZ and URAL, characterized by the presence of all-wheel drive, wide tires, variable transmission range, which provided confident movement off-road with speeds of 6–15 km / h, according to

technological speeds of machine–tractor units and combines on field works. It is fair to say that GAZ 52/53 trucks, which were used in various other areas, were still targeted as general purpose vehicles, not for fields and off–road. The objective need to develop the organization of production of trucks / road trains specialized in domestic technological transportation in agriculture was confirmed by the corresponding development of all–wheel drive equipment in Europe (almost after the Second World War – in Germany MB Unimog, in parallel now – all–wheel drive modifications MB Vano, MB Atego, MB Zetros, usually with a gross weight of 8 to 18 tons). Finally, in the USSR in 1964 NAMI developed the first so–called 4x4 agricultural truck NAMI 073 with a load of 4.5 tons and a gross weight of 9.6 tons on wide–length tires 1100x400x533 to work as part of a road train with a trailer with a gross weight of 6.5 tons.

In general, the structure of transport and technological support of agricultural production in Ukraine was quite rational, fit into the concept of agricultural cooperatives by M. Tugan–Baranovsky (which found its more effective implementation in market economies), but hasty dismantling of this system (without building an updated) led to the stratification of the agricultural sector from actually medium–sized enterprises to small (individual–family and farm with small areas of land) and ultra–large (agricultural holdings with large areas of leased land).

This leads to a certain reorientation of the type of wheeled vehicles from agricultural medium–sized enterprises to 2 different areas of use:

- small agriculture (including small farms) with a dominant small wheeled machinery (tractors of traction class 0.6–1.4 tons and trucks with a load of 1–1.5 tons, trailers with a load of 1–1.5 tons);

- agro–holdings, dominated by wheeled tractors of traction class 3.0–5.0t (gross weight 10.3–16t, without attachments or trailers), which use three–axle trailers with a gross weight of up to 30t for transport operations (with a load of ball coupling of the tractor) with a trailer up to 3 tons) and general purpose road trains with a gross weight of up to 40 tons for main transportation of products from collection

points in farms on paved roads to wholesale consumers, elevators, ports and others. The same wheeled tractors with trailers or remnants of the fleet of so–called multi–purpose all–wheel drive vehicles with trailers, mostly from Soviet times (MAZ, KAMAZ, URAL), are used for domestic technological transportation.

The relevance of all–wheel drive low–tonnage truck, in fact N1category (gross weight up to 3.5 tons) for individual farms and farms that grow products for sale, and obviously known in practice in the EU and Russia, where in addition to existing all–wheel drive UAZ, GAZ Gazelle / Sobol has developed and started production of low–tonnage universal trucks and tractors with a capacity of 0.3–0.8 tons (gross weight 1.7 tons – 3.2 tons) – NAMI 1337/1338/2238, which in the range of gear ratios are capable, except for transport, use the main functions of a mini–tractor for tillage and plant care, ie the segment of ultralight Unimog, Fig.2 It should be noted that this practice of small universal wheeled machines for small farms is common in Italy, France, Austria, Japan, Canada, where there are more than a dozen productions of this equipment and that would be suitable for the scope of the Kharkiv plant of tractor self–propelled machines.

Undoubtedly, these low–capacity wheeled vehicles are not of concern in terms of specific pressure and soil compaction, ie in terms of agri–environment, and the main problem is the support of the state and banking institutions to organize the development and production of wheeled vehicles.

However, in light of the intensive growth of the total area of agricultural land and sales of large agricultural holdings, the problem of relevant transportation is not only the well–known congestion of road trains with asphalt–paved roads, but also a much more serious problem of excessive compaction of fertile lands, their degradation as the basis of the agrarian economy.

Today in Ukraine, tractor trains dominate in large agricultural holdings on domestic transportation. According to (Rebrov *et. al* 2018), the distances of domestic traffic are in the range of 5–15 km (in Germany – up to 16 km), occasionally with the share of paved

roads. At the same time, according to the experience of the EU countries, road transport, which accounts for up to 60–70% of the volume of transport work, is preserved in these transportations in medium and large agricultural holdings and enterprises. The reason for this is shown in the relevant studies,

there is a significantly higher efficiency and lower costs compared to tractor transport, in particular, on the example of tests of a Fendt 933 wheeled tractor with a three-axle trailer (technical data – Table 1) and a road train – a 4x4 MB Zetros 1833 tractor and a three-axle SGT semi-trailer, fig. 2.



**Figure 1.** Tractor Fendt 933 + SGT 30



**Figure 2.** MB Zetros 1833 +SGT 32

Basic technical parameters of typical wheeled road trains on domestic transportation in the agricultural sector (Rebrov *et. al* 2018).

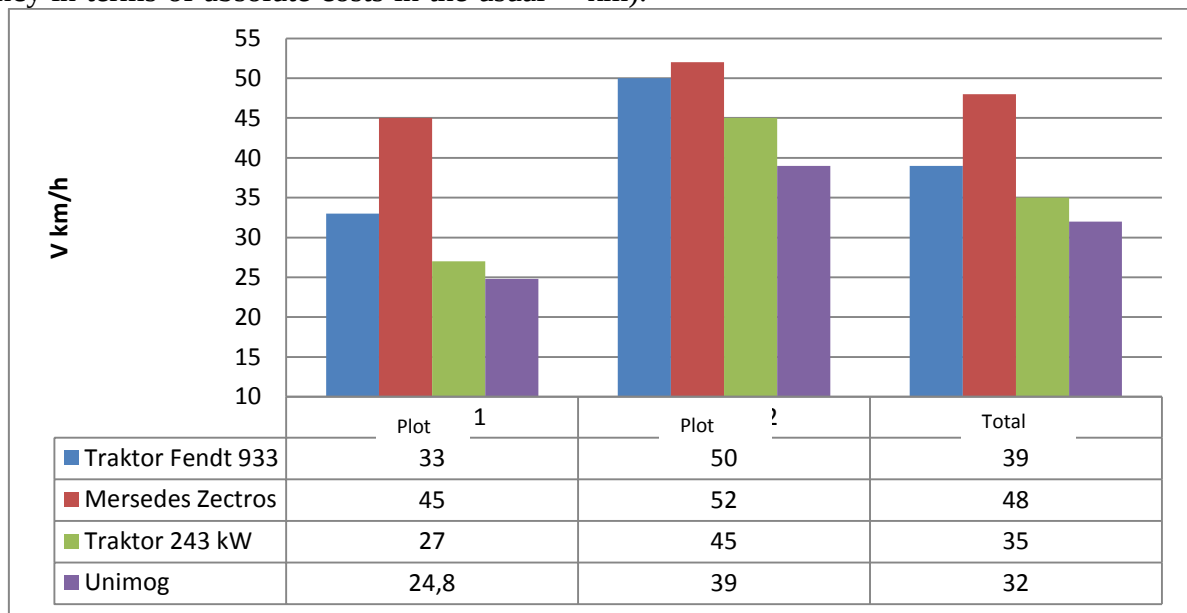
| Name                           | Power<br>kW (hp)  | Equipped<br>weight, t | Tires, size<br>(front / rear)     | Trailer,<br>equipped<br>weight, t | Cargo<br>volume of<br>platform,<br>m <sup>3</sup> | Total<br>weight of<br>the<br>trailer, t | incl. on<br>the<br>coupling<br>device, t |
|--------------------------------|-------------------|-----------------------|-----------------------------------|-----------------------------------|---------------------------------------------------|-----------------------------------------|------------------------------------------|
| Fendt<br>933+SGT<br>30         | $\frac{243}{330}$ | 10,76                 | $\frac{650/65R34}{710/75R42}$     | 10,5                              | 56,0                                              | 30,0                                    | 3,0                                      |
| MB<br>Zetros<br>1833+SGT<br>32 | $\frac{240}{326}$ | 8,1                   | $\frac{560/60R22,5}{600/50R22,5}$ | 10,0                              | 56,0                                              | 32,0                                    | 8,0                                      |

At the same time, the maximum (and legally permitted) speed of a Fendt tractor with a trailer is 60 km / h, and the maximum speed of the MB Zetros road train was limited to the same value (this allows you to work in Germany according to the law: on Saturday and Sunday). The volume of domestic traffic (from the field to the collection point) was 27.8 km, of which 15.6 km – the field, dirt roads and rural streets with paved roads in need of repair (section 1), and 12.2 km sections of the asphalt road of local importance (approximately II category according to Building Code). Both road trains were loaded up to the permissible 40 t of total weight (ie MB Zetros road train carried 2.5 t more cargo due to

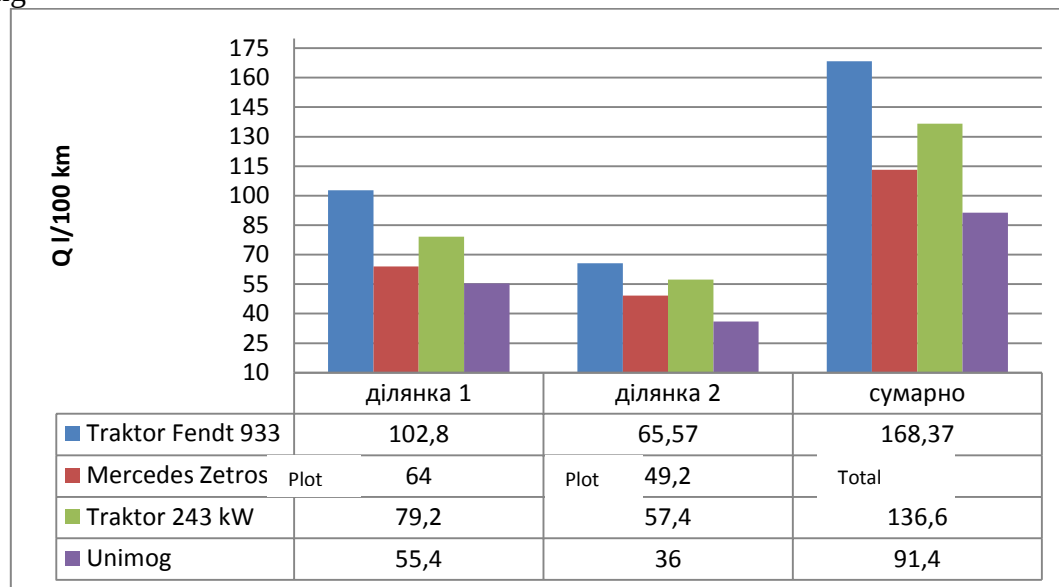
lower equipment weight). The tire pressure is regulated according to the manufacturer's regulations for such transport work, ie 1.4 / 1.9 bar of the front / rear tires of the tractor and 2.5 / 3.2 bar of the respective vehicle. The tire pressure of the trailer or semi-trailer is the same 3.0 bar. In addition to the fuel speed characteristics, the vert acceleration in the driver's seat as an indicator of the specific working conditions of drivers was also indicated. Fig. 3 presents the absolute values obtained during the comparative experiment for both the above and transportation in general, and in table 2 – the corresponding specific ratios of indicators. At the same time, according to the

experimental data, we also assessed the fuel efficiency in terms of absolute costs in the usual

linear costs for tractors (l / h) and trucks (l / 100 km).



**Figure 3.** Average speeds of technological transport by trucks and wheeled tractors according



**Figure 3.** Linear fuel consumption Q of automobile and tractor road trains on domestic agricultural transportation (according to data (Rebrov, 2017)).

**Table 2.** Comparative assessment of fuel and speed characteristics and vibration loads, comfort of working conditions of the tractor driver and automobile road trains on domestic transportation (according to the results of the analysis)

| Section of the road | Average speed, % |     |       | Fuel consumption, % (l/h / l/100km) |     |       | Vibration loads of the driver % |    |       |
|---------------------|------------------|-----|-------|-------------------------------------|-----|-------|---------------------------------|----|-------|
|                     | 1                | 2   | total | 1                                   | 2   | total | 1                               | 2  | total |
| Tractor Fendt       | 100              | 100 | 100   | 100                                 | 100 | 100   | 100                             | 70 | 85    |
| Auto MB Zetros      | 134              | 100 | 123   | 60,2                                | 75  | 66    | 60                              | 50 | 55    |



Comparative analysis of the results shows the undeniable advantage and obvious efficiency of the use on domestic road in agricultural production of specialized road trains, providing 23–34% higher average speed and productivity while reducing fuel consumption by 39–34% and 34–40% reduction vibration loads on the human body (note that the permitted movement at a speed of 60 km / h on the local highway, as was accepted in this comparative study is not typical for wheeled tractors with trailers); tractors operated in Ukraine are limited to 40 km / h, which gives an additional advantage to a specialized road train).

Practically similar results for comparable transportation options were obtained in the study of the 243 kW tractor and the 310 kW MB truck in the study of the Department of Agricultural Engineering of the Technical University of Munich, the corresponding data are presented in Figures 3 and 4. At the same time, in addition to the above, we investigated 2 more transport options – with a tractor with a capacity of 121 kW (almost analogous to the T-150k) and a truck – Unimog with a capacity of 210 kW. The obtained results showed a significant reduction in fuel consumption of the tractor with a capacity of 121 kW (compared to a tractor with 243 kW) – an average of 10–12 l / 100 km (with a slight decrease in average speeds by 3–5.5 km/h). However, the efficiency of the universal Unimog with a trailer or semi-trailer deserves more attention, where average speeds and fuel consumption are almost comparable to all-wheel drive trucks larger than 100 kW power (at identical load capacity). It is obvious that qualitative co-refinement of the obtained results on all obtained combinations of technological transport of smaller tonnage is undoubtedly needed. It should also be noted, taking into consideration the seasonality of agricultural production, a much higher utilization rate of the actual type of Unimog tractor, which due to the existing 3-diagonal transfer case in the transmission, is used in agriculture and for cultivation of agricultural land (as a wheeled tractor).

Understanding the production capacity in Ukraine (KRAZ, overloaded production in

the field of transport engineering), we can see the obvious feasibility of developing and commercializing the actual specialized trucks 4x4 and related trailers for the agricultural sector of the economy in 2 classes:

- category N1 with a gross weight of up to 3.5 tons of semi-rope layout with uneven distribution of loads on the front and rear axles in terms of off-road.

- category N3, with priority as a dump truck with three-way drive unloading and work as part of the trailer road train, as well as...

- appropriate trailed equipment – uniaxial category 02 with a brake system of inertial pressure and two-three-axle, respectively, trailers and semi-trailers according to the scheme of so-called convergence of axles with pneumatic brake.

From the conditions of realities of domestic production the restored model of the tractor of categories N3 both for a road train, and trailer (with the extended wheel base) can be created on the basis of all-wheel drive model KrAZ-5233 4x4 model equipped with the centralized system of regulation of air pressure in tires which is urgently necessary from the point of view of the conditions of agro-ecology and passability.

Actually, from the conditions of agro-ecology, it is expedient to process and produce wide-size tires of dimension 560/60 R22.5 or 600/50 R22.5. The same tires are wider for both tractor (in the T-150K version) and automobile three-axle trailers with a load on the axle load of 8–8.5 tons and a semi-trailer, taking into account the realities of high-speed N3 heavy road trains on roads and off-road local traffic as a power of the N3 tractor unit which is sufficient to use of the Dentz diesel engine unified with T-150 with a displacement of 7.7 l of RF6MHB / 2013 series (200–220 kW), which will positively affect fuel economy and simplify repair service when using T-150K for tillage. Development and organization of production of large-scale three-axle agricultural trailers and semi-trailers real for domestic machine-building plants, subject to appropriate support from relevant state institutions, including the actual discount rate of the project

within 5–7% per annum (if the government wants to keep potential).

In practice, the above is also relevant for the problem of farm vehicles of category N1 / N2. Taking into account the level of profitability of their activities, the prospect of importing such equipment from Germany (MB–V 80–110 thousand euros), France or Italy looks illusory. On the other hand, the development of the actual farming system in the agricultural spectrum without the appropriate technical support is simply illusory.

### CONCLUSIONS

Technological transport in the agricultural sector of Ukraine is actually at the stage of formation. In fact, it is important to form a rational type for two uses – in small farms and large agricultural holdings. If the latter is realistic to use (with appropriate adaptation of structures) appropriate modifications of existing models of domestic HTZ and KRAZ (including in terms of import substitution), then for small farms (including in terms of pricing compared to imports) it is important to deploy low-capacity wheeled vehicles in Ukraine. From the European experience (after all, taking into account post-Soviet Russia) rational in this segment is the actual design of a universal low-tonnage machine type Unimog, which includes both the functions of a wheeled tractor class 0.6–0.8t, and all-wheel drive truck with onboard platform at 1–1.5 t.

### REFERENCES

Ignatov V. D. Organization of transportation of goods in the collective farms of state farms. M.: Rosselkhozizdat, 1978. 206 p.

Elisaev V. G., Labodaev V. D., Chernomorets N. A. Transport in agriculture. Minsk, Uradzhai, 1984. 151 p.

Belling Sohne WDr Bodendruck sohverer Ackerschlepper Fahrzeuge. Landtechnik, 1982. H.2. S. 16–24

DIN 19688 2000. Bodenbeschaffenheit – Ermittlung der Verdichtungsempfindlichkeit von mineralischen Unterböden aus der Schätzung der Vorbelastung./ *Deutsches Institut der Normung*.

Gisi U., Schenker R., Schulin R. Bodeneekologie.–2 Aufl. Stuttgart, Thienna Verlag, 1997. 328 s.

Bernhardt H. Landwirtschaftliche Transporte . Wo stehen wir und was sind die Herausforderungen. TU München, 2014. 405  
<https://www.alb-bayern.de/media/files/0001/bernhardt-landwirtschaftliche-transporte.pdf>.

Völkl L. K. W. Mercedes Zetros 1883 versus Traktor Fendt 933 / Fachhochschule Suedwestfalen. Soest, 2011. 219.

Ipatov A. A., Dzotsenidze T. D. Creation of new means of transport infrastructure development. Problems and Solutions. Moscow, Metallurgy Publishing House, 2008. 272 s.

Rebrov O. Yu. 2018. Distribution of allowable pressure on the ground of running systems of wheeled tractors on the territory of Ukraine. *Bulletin of NTU KhPI; Series mathematical modeling in engineering and technology, Kharkiv, № 27 (1303)*, p.110–116.

Rebrov O. Yu. 2017. Analysis of compliance of the maximum pressure on the soil of a tractor tire with agro-ecological requirements by the probabilistic method taking into account the soil and climatic conditions of Ukraine. *Bulletin of NTU; Series – Transport Engineering: Kharkiv, № 14 (1236)*, 2017 P. 110–116.

The first "farmer" NAMI. Creation of an off-road utility vehicle NAMI – 072 / electron, resource. Access mode: [http: / www.osnovnyje-srehstva/article.....](http://www.osnovnyje-srehstva/article.....)

DSTU 4521: 2006 Mobile agricultural machinery. Norms of action of running systems on the ground / Kyiv, Ukr NDNC; 2006–8p.





## THE IMPACT OF PROTECTIVE CLOTHING AND ITS QUALITY IN WAREHOUSE WORKLOAD

Katarzyna Markowska<sup>1</sup>, Taras Shchur<sup>2</sup>, Patrycja Struzik<sup>3</sup>, Tomasz Kawka<sup>4</sup>, Sina Khodae<sup>5</sup>

<sup>1</sup> *Silesian University of Technology, Faculty of Transport and Aviation Engineering, Department of Transport Systems, Traffic Engineering and Logistic  
Krasińskiego 8 Street, 40-019 Katowice, Poland  
e-mail: katarzyna.markowska@polsl.pl*

<sup>2</sup> *Lviv National Agrarian University, Faculty of Mechanics and Energy, Department of Cars and Tractors, Volodymyr Great str. 1, Dubliany, 80381, Ukraine,  
e-mail: shchurtg@gmail.com*

<sup>3</sup> *Silesian University of Technology, Faculty of Transport and Aviation Engineering, Department of Transport Systems, Traffic Engineering and Logistic  
Krasińskiego 8 Street, 40-019 Katowice, Poland  
e-mail: patrycja.struzik1@gmail.com*

<sup>4</sup> *Silesian University of Technology, Faculty of Transport and Aviation Engineering, Department of Transport Systems, Traffic Engineering and Logistic  
Krasińskiego 8 Street, 40-019 Katowice, Poland  
e-mail: [tomasz.kawka@polsl.pl](mailto:tomasz.kawka@polsl.pl)*

<sup>5</sup> *K. N. Toosi University of Technology, Faculty of Industrial Engineering, Department of Industrial Engineering, Industrial Engineering - Logistics and Supply Chain  
No.7.Pardis Ave.Molasadra. Vanak Sq.Tehran.Iran.  
e-mail: s.khodaee@email.kntu.ac.ir*

**Abstract.** This article presents the problem related to protective clothing, describes the concepts of protective clothing and its division as well as analyses the accidents which occurred in the shipping warehouse. A questionnaire study was also conducted in relation to warehouse worker preferences regarding protective clothing.

**Keywords:** warehouse worker, safety gear, protective clothing, accident at work

### INTRODUCTION

The purpose of the article is to draw attention to the fact, that protective clothing is an obligatory element of work in a warehouse. Its selection plays a key role in ensuring the safety of employees. The article presents the impact of the quality of protective clothing on warehouse works. It describes the result of wearing incorrectly selected clothing and accidents in the warehouse that occurred as a

result of inadequate safety gear, as well as a survey conducted among warehouse workers regarding their preferences in relation to protective clothing.

### THE IMPACT OF PROTECTIVE CLOTHING AND ITS QUALITY IN WAREHOUSE WORKLOAD

Protective clothing acts as a replacement for personal clothing, covers the worker and protects him from hazards. It is not intended for work that results in intensive staining with substances harmless to health, nor is it intended for work in which there are factors that accelerate the deterioration of the clothing, or the cleanliness of the manufactured product is required (Laing, 2008).

In accordance with Art 2377 § 1. of the Labour Code, the employer is obliged to provide the employee, free of charge, with protective clothing and footwear that meets the

requirements of Polish Standard. This is to protect against the effects of harmful and hazardous to health factors that occur in the work environment, as well as inform the employee how to use personal protective equipment (Polish Law, 2020). Simultaneously, the employee is obligated to comply with the health and safety regulations and rules. In particular, the employee must use collective protection measures, personal protective equipment, use working clothes and footwear as intended (Krzyśków, 2013).

Protective clothing can be divided depending on: harmful factors and the guaranteed area protected by it. We also divide clothing taking into account the type of risk, which include chemical, biological, mechanical and thermal factors, electromagnetic radiation and electrocution, protecting against weather conditions, water and humidity, clothing used in potentially explosive environment, high-visibility clothing (Bartkowiak *et al.* 2019).

Undoubtedly, protective clothing should be selected in terms of employee's body dimensions, height and particular measurements. On the other hand, the employer should start the selection of protective clothing by identifying the type of hazards and defining all exposed parts of the employee's body to the hazard.

According to the standards established by the European Directive 89/686/EEC, there are

three categories of protective clothing. The first category is protective clothing that is designed to protect against a minimum hazard. This category includes workwear and clothing made of impregnated, protective fabric. It most often protects against light dirt, harmless mechanical damage and weather conditions. This clothing does not need to be certified. The second category is related to clothing, the task of which is to protect against specific factors that do not pose a threat to the life of the employee and do not lead to serious and permanent damage to health. It includes cut-resistant aprons, high-visibility clothing, and protective clothing against specific factors that do not pose a threat to the life of the employee and do not lead to serious and permanent damage to health. It includes cut-resistant aprons, high-visibility clothing, and protective clothing against harsh chemicals. The third category includes clothing that protects against the factors most threatening to the life and health of the employee. Clothing in this category protects against ionizing radiation, temperatures above 100 degrees C, extensive splashes of hot substances, clothing protecting against temperatures below -50 degrees C and clothing designed to work under high voltage. In Table 1 presents a list of allocation and consumption of protective clothing at work, in the position of a warehouse worker.

**Table 1.** List of allocation and consumption of protective clothing at work, in the position of a warehouse worker

| Job description                                                              | Type | Clothing and gear set                       | Item service life |
|------------------------------------------------------------------------------|------|---------------------------------------------|-------------------|
| Warehouse worker                                                             | W    | - beret                                     | 12 months         |
|                                                                              | or   | - hat                                       | 12 months         |
|                                                                              | W    | - apron                                     | 9 months          |
|                                                                              | or   | - dungarees                                 | 9 months          |
|                                                                              | or   | - clothing                                  | 9 months          |
|                                                                              | W    | - leather boots on a rubber soles           | 12 months         |
|                                                                              | S    | - protective gloves                         | tw                |
| Work in outdoors                                                             | S    | - raincoat                                  | tw                |
|                                                                              | or   | - rain jacket                               | tw                |
| Work in outdoors and in rooms with insufficient heating during winter season | S    | - insulated cap                             | 2 ws              |
|                                                                              | S    | - insulated clothes                         | 3 ws              |
|                                                                              | or   | - insulated jacket                          | 3 ws              |
|                                                                              | or   | - insulated vest                            | 3 ws              |
|                                                                              | S    | - rubber covered felt boots                 | 2 ws              |
|                                                                              | S    | - insulated leather boots on a rubber soles | 2 ws              |
|                                                                              | or   | - oil-proof insulated boots                 | 2 ws              |
|                                                                              | S    | - insulated gloves                          | tw                |

Explanation:

W – Work clothing or footwear

S – Safety clothing and footwear

ws – winter season

tw – till worn-out.

Due to the specificity of his duties, a warehouse worker needs clothing that will not restrict movement, will be comfortable, at the same time solidly made, of a dirt-resistant material and having numerous pockets for tools and utensils that make work much easier. The selection of clothing is also important due to frequent temperature changes in the shipping warehouse. The duties of a warehouse worker include accepting and checking deliveries of goods, unloading goods, planning warehouse space and placing goods in it, labelling and placing products in designated places, picking orders, loading orders for delivery trucks, operating devices, e.g. a pallet truck and forklift, inventory control, stocktaking of the warehouse, cooperation with other departments (Michalik, 2019).

### ACCIDENT ANALYSIS

The article analyses two accidents that occurred in the warehouse. The causes of the accidents were poorly selected protective clothing, as well as the employee's inattention and non-compliance with occupational health and safety regulations. The first accident was caused by an incorrectly sized workwear. During the activities, the employee wore loose pants, which were additionally too long. His head, in turn, was protected by a helmet that did not have the appropriate size adjustment. While working, an employee tripped over a

trouser leg and fell. The helmet slipped off his head during the fall. The result of the accident was a head wound, and the cause of the loss of balance while wearing too large and too loose pants.

The second accident was the fault of the employee because the employee did not comply with the employer's requirements regarding the use of protective clothing during the activities. The employee did not use toe protecting shoes with toecaps. While transporting a pallet, a manual pallet truck ran into the foot.

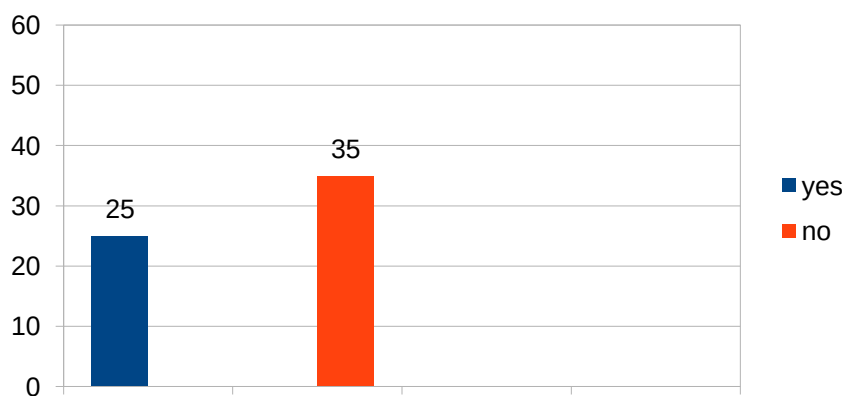
### SURVEYS CONCERNING THE PREFERENCES OF PROTECTIVE CLOTHING BY WAREHOUSE EMPLOYEES

A survey on the preferences of protective clothing was carried out in 2021 among 60 employees of the shipping warehouse. Thanks to the research, it was possible to determine what warehouse employees expect from protective clothing and what aspects are important to them.

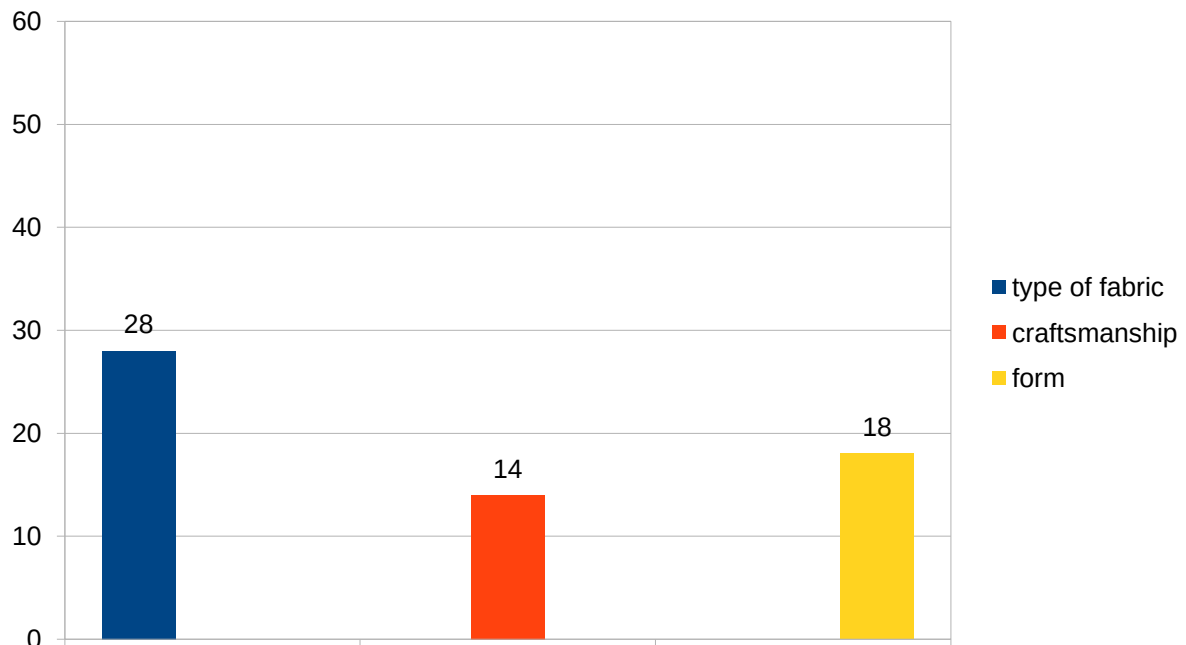
Figure 1 shows the interest of warehouse workers in the composition of the material used in protective clothing.

According to the conducted research, it appears that 25 respondents pay attention to the composition of the material used in the production of protective clothing, while 35 people do not pay attention to the composition.

Figure 2 shows what warehouse workers pay attention to, when wearing protective clothing.



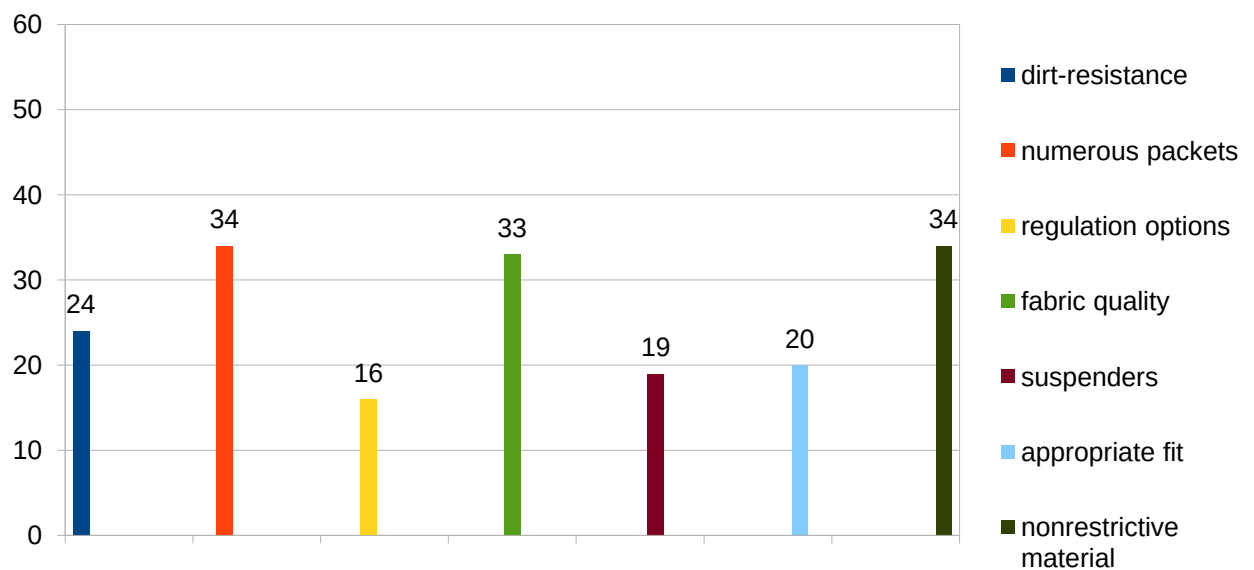
**Figure 1.** Warehouse workers interest in material composition



**Figure 2.** Warehouse worker preferences

28 warehouse workers pay attention to the type of fabric in their protective clothing. For 14 employees, the quality of workmanship is important, while 18 respondents indicated design as an important criterion for protective clothing.

Figure 3 shows the important elements in the use of protective clothing that covers the lower limbs. Each respondent could choose up to 3 answers.

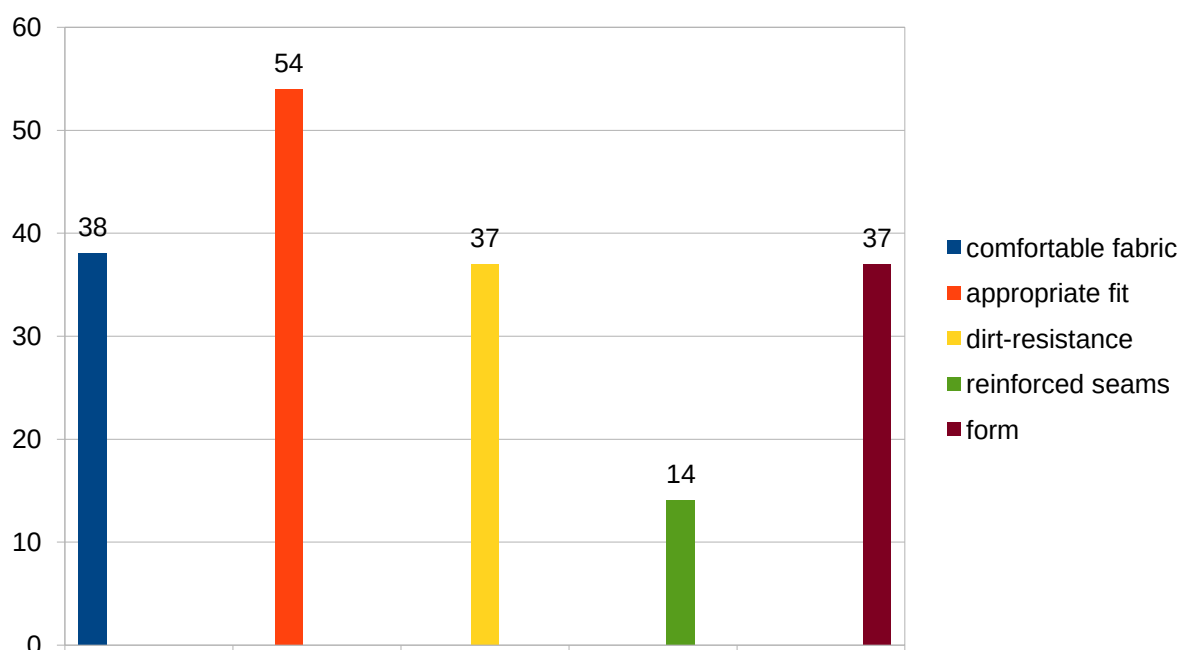


**Figure 3.** Important elements of clothing covering lower limbs

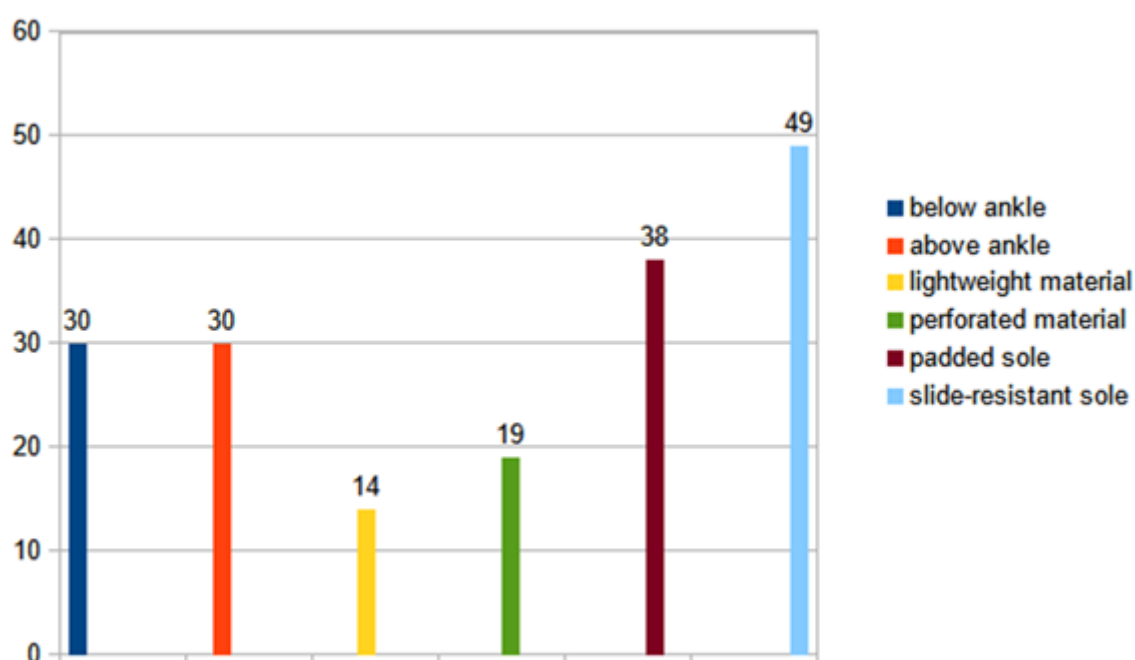
Based on the survey results, 24 warehouse employees consider the dirt-resistant material to be important, and 34 respondents mentioned numerous pockets as an element to facilitate work. Respondents considered regulation option the least – 16 times – while 33 respondents indicated the quality of the material. For 19 employees,

suspenders are important in clothing, while one more person chose an appropriate fit. 34 people consider it important that the material allows freedom of movement.

Figure 4 shows important elements in the use of protective clothing that covers the upper limbs and torso.



**Figure 4.** Important aspects of clothing that protect the upper limbs and torso



**Figure 5.** Safety footwear preferences

The most votes – 54 – were cast for appropriate fit. For 38 respondents, comfortable fabric is an important factor in protective clothing. 37 people indicated dirt-resistance and form received the same amount of votes, while 14 workers indicated reinforced seams as important.

Figure 5 shows safety footwear preferences

Votes are evenly split between below ankle and above ankle safety shoes. 14 people

prefer the lightweight material and 5 more would like safety shoes with vents. 38 respondents favour a padded sole, while slide-resistant sole was chosen 49 times.

## SUMARRY

The research shows that incorrectly chosen clothing can cause accidents at work. Employees willingly participated in the survey

in which they were asked about their preferences for protective clothing. Workers mostly focused on convenience and comfort, while not forgetting about safety. It is important for employees to consider the craftsmanship in their protective clothing. Employees prefer a material that is comfortable, allows freedom of movement, and at the same time resistant to dirt. It is important for the respondents that the size of the clothing is properly selected, thanks to which it is safe and serves to protect the worker against possible threats. The respondents appreciate numerous pockets that allow them to have the necessary utensils and tools with them. In safety shoes, respondents appreciate the non-slip and cushioned sole. In order to meet the expectations of employees, it guarantees them, above all, safety, as well as comfort and improvement of the quality of work performed. Employees who will be able to actively influence the quality of clothing provided by the employer will certainly derive more pleasure and satisfaction from their duties.

#### REFERENCES

- Laing R. M. 2008. Protection Provided by Clothing and Textiles Against Potential Hazards in the Operating Theatre. *International Journal of Occupational Safety and Ergonomics*, vol. 14, no. 1, 107-115,
- Polish Law. 2020. Art. 237(7) Ustawy z dnia 26 czerwca 1974 r. Kodeks pracy (Dz. U. z 2020 r. poz. 1320, z 2021 r. poz. 1162) (in Polish).
- Krzyśków B. 2013. Basic guidelines of OSH in warehouses - legal status. *Bezpieczeństwo Pracy – Nauka i Praktyka*, 1, p. 4-6 (in Polish).
- Bartkowiak G., Greszta, A. 2019. Determination of a Comfort Class for Protective Clothing Based on Ergonomic Tests. *Fibres & Textiles in Eastern Europe*, 2019, 5 (137), p. 65-74.
- Michalik J. 2019. Selected aspects of safety, hygiene of work and ergonomics at a work stand warehouse in a selected enterprise. *Gospodarka Materialowa i Logistyka*, 5, p. 440-453 (in Polish).

## **Table of contents**

***Nanka O. V., Bakum M. V. Nagaev V. M., Krekot M. M., Sementsov V. V.,  
Mityashkina T. Yu., Shchur T. G.***

Investigation of dimensional characteristics of pea and millet grain..... 5

***Goshko M.***

The outer temperature effect on the of led lamps working characteristics..... 13

***Kharchenko S., Haiek Y., Bazhynova T., Kovalyshyn S.***

Efficient use of aspiration systems of grain and seed cleaning machines..... 19

***Pankova O., Sirovitski K., Kharchenko S.***

Proteolysis of different varieties of barley depending on seed treatment by monochromatic optical 31  
radiation of the red range.....

***Kharchenko S., Lytvynenko V., Kovalyshyn S.***

Prospects for increasing the efficiency of pneumatic separation channels in cleaning grain and seed 35  
materials.....

***Syromyatnikov Y., Sementsov V., Sementsov V., Nanka O., Vitsotenko N.***

Improving the stability of the movement of the section of the combined machine for soil 41  
preparation and sowing.....

***Krainyk L. V., Syvulka P. M., Khudaverdian H. A., Gabriel Y. I.***

Agricultural transport – the type and structure formation of the wheeled vehicles fleet..... 51

***Markowska K., Shchur T., Struzik P., Kawka T., Khodae S.***

The impact of protective clothing and its quality in warehouse workload..... 59