INCREASING THE PERFORMANCE OF CYLINDRICAL SEPARATORS FOR CEREAL CLEANING, BY USING AN INNER HELICAL COIL

CREȘTEREA PERFORMANŢELOR SITELOR CILINDRICE PENTRU CURĂŢIREA CEREALELOR, PRIN UTILIZAREA UNEI SPIRE INTERIOARĂ ELICOIDALĂ

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DOI: https://doi.org/10.35633/inmateh-62-26

Keywords: *cylindrical rotary separators, wheat grains, contaminant extraction*

ABSTRACT
Rotary seed sorters used for wheat processing show some functional advantages in eliminating persistent contaminants, especially due to the more aggressive treatment applied to the processed material. The objective of this paper was to design a new constructive subassembly that would increase the performance of rotary sorters used for extracting various contaminants from seeds. By testing a pilot stand that reproduces the operation of a professional equipment and developing mathematical models that fits the main operating parameters, it was possible to identify the new characteristics needed to improve cylindrical sieves and to optimize the functioning of this equipment.

REZUMAT
Sortatoarele rotative utilizate în procesarea grâului, prezintă unele avantaje funcționale în eliminarea contaminanților persistenți, în special datorită tratamentului mai agresiv aplicat materialului procesat. Obiectivul lucrării a fost acela de a crea un nou subansamblu, care să crească performanțele echipamentelor rotative de extragere a contaminanților din semințe. Prin testarea unui stand pilot care reproduce fidel funcționarea unui echipament profesional și prin modelarea matematică a principalilor parametri de funcționare ai acestuia, s-au putut identifica noile caracteristici necesare pentru îmbunătățirea sitelor cilindrice, precum și optimizarea modului de funcționare a acestor echipamente.

INTRODUCTION
Axial and tangential rotary wheat separators, are considered to be most suited sorters when processing wheat that is fixed in different conglomerations or when the contamination with leaf and light straws is relatively high. Rotary sorters can be integrated successfully in the pre-cleaning section, before silo loading, when larger perforated sieving sheets are usually used, or at the cleaning section before milling, when smaller perforated sieving sheets are preferred.

Equipment that uses rotary motion for separation are less used than vibrating sorters due to their increased complexity, however they can bring important improvements to the separation process, especially for crops that have high contamination, high humidity, or when contaminants are stuck to the seeds.

Compared to other treatment methods, separation by rotation has the advantage of producing a more aggressive treatment of wheat, allowing easier release of the grain when caught into conglomerations. However, the process involves some disadvantages related to the fact that separation achieved by rotation is usually breaking up the straws, resulting in a reduction of the contaminating particles volume and a worse impurity retention (*Casandroiu T., 1993; Bracacescu C. et al., 2016)*.

Păun A. et al., (2018) studied the design and installation of cylindrical sieves combined with counter-current suction and separation using a rotary seed separator for the elimination of large contaminants (e.g. straw). These large contaminants cause problems for the separation process, because they do not come out easily through the perforations of the sieves' outer wall, affecting the cleaning process. *Jianbo, Y. et al., (2018),* have tested rotary sieve speeds, assessing quantifiable losses associated with the increasing of rotational speeds.

Another important parameter, namely the cylindrical diameter, was researched by *Shi X. et al., (2018), Yuan J. et al., (2018),* and *Krzysiak Z. et al., (2020)*, for establishing relationships between the increase in diameter in relation to the separation efficiency and average axial grain speed.

Mathematical modelling for the evaluation of various cylindrical sieves parameters have been intensively studied in order to optimize their efficiency (*Naumenko M. et al., 2018; Badretdinov I. et al., 2020; Voicu Gh. et. al., 2008*), bringing improvements to the design and construction, and obtaining superior quality of the grains.

An element which has to be taken into account when using rotary separators on an industrial scale is the high technological complexity. They must have increased efficiencies, while allowing ease of maintenance at low costs, otherwise the performance of this equipment is greatly influenced by too frequent repairs.

Our goal was to assess an experimental rotary wheat sorter functioning, identify all the working issues that may arise during operation and propose some design improvements related to the main identified shortcomings. In addition, a number of observations made by farmers using these cleaning systems has been considered.

MATERIALS AND METHODS

A pilot experimental stand has been used to test the seed rotary sorters performances, varying a series of parameters to succeed in simulating the operating conditions of a similar industrial equipment. The analyses performed on the experimental stand have been associated with the theoretical calculation of the rotary sorters, in order to determine which design specifications could be improved to increase equipment performances.

All the important features identified in theory were varied when testing the experimental stand. This allowed identifying important characteristics to be considered when designing new equipment and legitimate certain improvements on the installation design, in order to streamline the main shortcomings.

Figure 1 shows the experimental stand that is in the custody of INMA Bucharest for evaluation and for improving its specifications. During operation, the wheat containing different types of contaminants of known dimensions and quantities, is introduced in one of the feeding inputs *(5)*, provided with a quantity dosing flap. The rotating sieve drive motor *(1)* drives the sieve *(2)* unidirectional by means of an axis of rotation *(4)*. The sieve is automatically cleaned by the brush *(3)* during the rotation preventing wheat or impurities to get trapped in the sieve holes. Impurities will be collected in the impurity collection trays (*6)*, which will allow the analysis of the separation of the masses of impurities along the sieve, this being an important element in the evaluation processes. Total mass of clean wheat is then stored in a special tray *(7)*, while the angle of inclination of the sieve is varied by means of the hydraulic jack *(9)*. The equipment is equipped with a start/emergency stop button *(8)*.

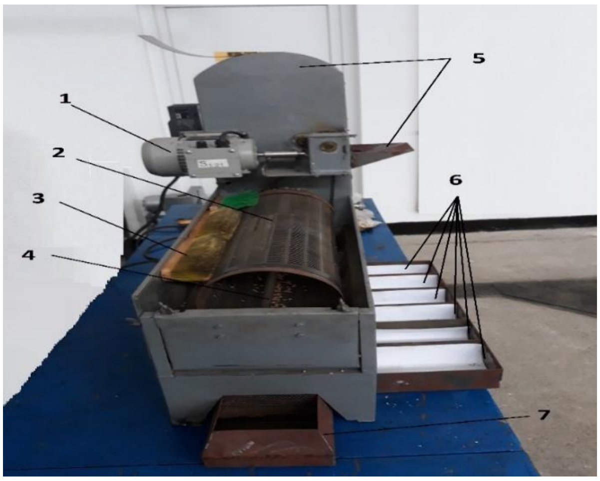


Fig. 1 - Rotary wheat separators pilot experimental stand
(1) drive motor, (2) sieve, (3) brushes, (4) axis of rotation, (5) feeding inputs, (6) impurity collection trays, (7) clean wheat tray, (8) start / emergency stop button, (9) hydraulic jack

The row material inserted into the rotating cylindrical sieve, was composed of mixtures of wheat and other contaminating seeds, free and in conglomerations, driven gravitationally from the feeder when lifting the hopper retainer. The impurities separated by the wheat grains fall into the collecting chambers through the sieve holes, as long as the clean material advances along the length of the sieve.

The material advancement is made either by the sieve inclination at a customizable angle, either by the rotational speed imposed to the sieve.

The mixture of seeds introduced inside the cylindrical sieve, acquires a rotational movement, along with the rotating sieve and a translational movement along the length of the sieve.

The advancement of the seeds inside the equipment takes place conditioned by the rotating sieve inclination angle. This is one of the equipment adjustable parameters which generates the speed of advancement of the processed material and might be varied depending on the level of seed contamination.

These movements allow the mixture to separate into fractions, so that the small seeds come out through the sieve holes, while the big seeds move along the sieve, towards the end of the cylinder, being collected separately.

Depending on the angular velocity of the sieve (ω), the following outcomes are drawn towards the movement of the seed mass, illustrated by the following three distinct cases.

- Case A when high rotation speeds are applied to the sieve ($\Omega = \omega$; $\omega >>$), (where Ω is the angular speed of the absolute movement of the seed), it is observed that seed mass adheres to the inner surface of the cylindrical sieve and rotates with it (Fig.2a). In this case the separation process does not take place, and the speed at which this phenomenon occurs is called the critical speed of the sieve (relative rest phase);
- Case B when applying angular velocities lower than the critical speed ($\Omega = \omega$), the seed mass adheres to the surface of the cylindrical sieve, rotating with it up to detachment point - DP1 (where normal reaction $N = 0$), after which they detach and a sliding process begins following a parabolic trajectory up to landing point – LP1, point of contact with the sieve, (Fig.2b);
- Case C when applying low angular velocities to the cylindrical sieve, the seed mass slides in the opposite direction to the movement, rotating around the cylindrical sieve rotation axis, with an angular velocity $\Omega < \omega$. The mass of seeds, being driven in rotational motion with an angular velocity $\Omega < \omega$, causes some of the seeds to pass through the sieve holes, while the rest of the seeds detach and begin to fall after a parabolic trajectory until the landing point – LP2, (Fig.2c).

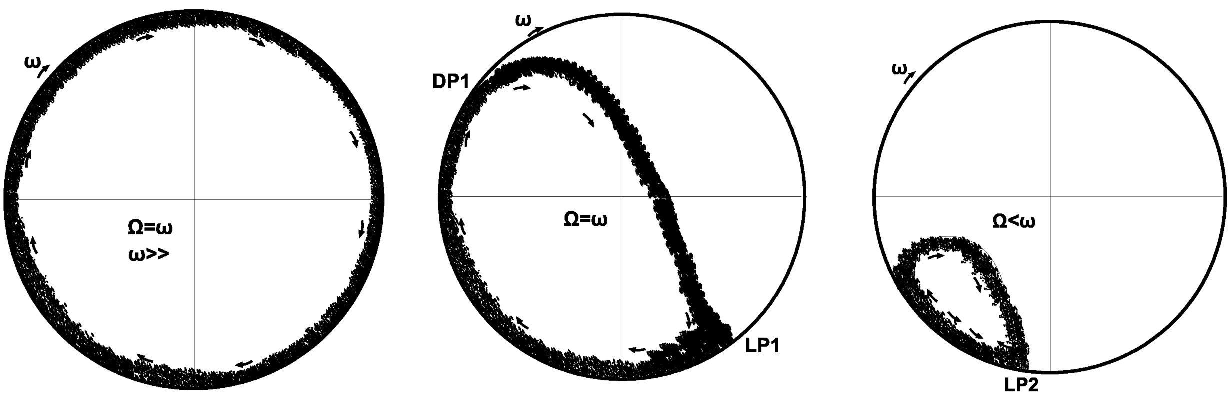


Fig 2a Fig 2b Fig 2c

Fig. 2 - The movement of the seed mass inside the sieve, depending on the angular velocity of the sieve
Case A (Fig.2a) *when high rotation speeds are applied to the sieve;*
Case B (Fig.2b) *when applying angular velocities lower than the critical speed ($\Omega = \omega$);*
Case C (Fig.2c) *when applying low angular velocities to the cylindrical sieve*

However, angular velocities from the cylindrical sieve are depending on the mass of seeds entering the process, being observed that a very high intake of seeds would block or negatively affect the separation. A problem identified in practice is that as the volume of seeds introduced for processing increases, then the processing efficiency decreases significantly. Therefore, the productivity of the equipment depends on the length of the sieve, the angle of inclination, the speed of rotation and the mass of seeds introduced. The mass of seeds introduced is also dependent on the level of contamination, which is why we have introduced when testing the equipment raw material with different types and levels of contaminants.

The row material entering the cylindrical sieve, performs a complex movement relative to the sieve axis due to the rotational movement and inclination of the sieve, forming a layer that will have a certain shape and size in cross section, separation being achieved mostly in a single quadrant (Fig.3).

At the beginning of the sieve, the contamination separation will be maximum, while the mass advances along the sieve, the contamination separation decreasing. To be able to observe the percentage of contaminants that are discharged through the holes of the sieve, along its entire length, contamination seeds will be collected using six collection trays, placed along the entire length to be analysed.

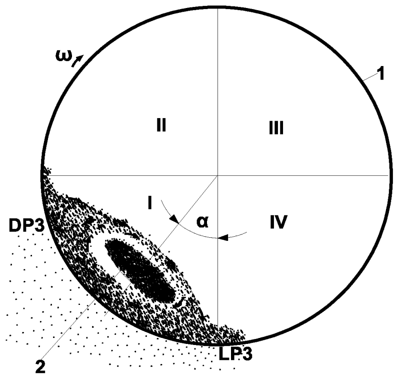


Fig. 3 – Movement of seeds in the layer, inside the sieve

Note: modified diagram after Jianbo, Y. et. al., (2018)

1– Cylindrical sieve; 2 - the immobile nucleus; DP3 -detachment point; LP3 - landing point

The seed layers that are in contact with the surface of the cylindrical sieve move in the same direction of rotation with the sieve and must have a lower speed than the sieve, therefore there is a relative movement between seeds and sieve – this being a mandatory condition for the separation process. In the inferior layers, the seed layers will have lower speeds, the speed of the neighbour layers gradually decreasing, cancelling in the centre, where the immobile nucleus is formed (Fig.3: pos.2-the immobile nucleus).

It is needed that the operating regime of the sieve to ensure the relative movement (sliding) of the seeds on the surface of the sieve, this being an essential condition for achieving the separation.

The seeds are driven in the same direction of movement with the sieve, up to the area where they collapse and change direction, (point *DP3*, Fig. 3), contrary to the first row. The seeds will then return to base in contact with the sieve at landing point *LP3* and at the same time advancing along the length of the sieve to the opposite end.

In addition, a seed mixing area (MA) was identified, the area where the seeds mix between layers appears, due to the rupture caused by gravity. This aspect is extremely important because the seeds in the upper rows also come into contact with the sieve to be subjected to separation through the holes, allowing the process to take place.

The importance of the process of mixture in the efficiency of the separation process has led us to develop methods to improve the mixing of seeds in layers. One of our design proposals was to install a special designed coil inside the sieve, which would allow a better mixture of the seed layers, so that the seeds from the immobile nucleus, will get more rapidly in contact with the sieve surface, thus increasing efficiency.

Avoiding the formation of the immobile nucleus was one of our priorities because the seeds existing in this nucleus are not subjected to the separation process. The formation of the immobile nucleus is conditioned especially by the feed flow and the thickness of the seed layer. Our proposed technical improvement correlates the feed flow with the tilt angle and the newly design coil in order to have a better contact of seeds from the immobile layer to the surface of the sieve.

The analysis involved the assessing rotary sieve characteristics based on certain models, evaluating the trajectories of the grains detached from the inner surface of the sieve and the speed of movement of the sorted material inside the sieve after a helical movement given by the inclination of the sieve towards the horizontal.

We have used *Panturu et. al., (1997)*, and *Krasnicenko et. al., (1964),* for the calculation of the trajectories of the grains detached from the inner surface of the sieve, and to find the movement of the material to be sorted along the cylindrical sieve during the roto-translational motion.

In order to mathematically model the seed sorting process using rotary cylindrical sieves, we have used the π Theorem (Buckingham's Theorem). Our purpose was to obtain a mathematical model that takes into account the specific loading rate subject to separation, using rotating sieves. From the dimensional analysis, the following parameters that influence the selection process have been considered: specific loading flow subject to sorting q (kg/s^3); the distance between the turns of the coil inside the sieve, De (m); speed of grains advancement in the helical movement V_M (m/s); the speed of the turn inside the sieve $n1$ (s^{-1}); length of the sieve, l (m); the content of impurities (%); the efficiency of the selection process being evaluated by the amount of selected seed Qs (kg).

The default function that describes the dimensional selection process, for homogeneous dimensional terms, is:

$$f(Q_s, q, V_M, n_1, D_e, l, c_i) = 0 \tag{1}$$

Considering as determining quantities the group (q, V_M, n_1), and calculating according to Buckingham's Theorem the dimensionless complexes of the selection process (similarity criteria) for the physical parameters (QS, De, l), we have been found the dimensionless matrix of the 6 parameters in relation to the fundamental quantities L (length), M (mass), T (time).

After setting the conditions for the dimensionless complexes, and solving the obtained systems of linear equations, the relation of the quantity of seed sorted using rotating cylindrical sieves was determined, by separating the term Qs from the criterion equation.

$$Q_s = qn_1^3 \cdot \varphi_1\left(\frac{D_e \cdot n_1}{V_M}, \frac{l \cdot n_1}{V_M}, c_i\right) = 0 \tag{2}$$

The mathematical model of the multiplication of powers was proposed, finally obtaining the equation (1), and after logarithmic linearization, the relation (2) was obtained.

$$Q_s = k^* q \cdot n_1^{(3+\alpha_1+\alpha_3)} \cdot D_e{}^{\alpha_1} \cdot V_M{}^{(-\alpha_1-\alpha_2)} \cdot l^{\alpha_2} = 0 \tag{3}$$

$$\ln Q_s = \ln k + \ln q + (3 + \alpha_1 + \alpha_2)\ln n_1 + \alpha_1 \ln D_e + (-\alpha_1 - \alpha_2)\ln V_M + \alpha_2 \ln l \tag{4}$$

Data processing envisaging the working process of rotating cylindrical sieves was performed by regression analysis. Constants' values from Eq. 3 are obtained by regression analysis when the exponents are calculated by linear regression based on experimental data. The feed rate of the material to be sorted (V_M) varies within the limits of 0.075 - 0.6 m/s, while the values of coil speed (n_1) were in the range 0.2 – 0.8 (s^{-1}), and the distance between the elements of the coil (De) have been first considered a fixed value of 0.0012 m. It was considered a specific load (q) of 0.555 kg/s^3 and a length of the sieve l of 0.3 m. In Fig. 4 there are presented the variation curves of the sorted seed mass (Qs), resulting from Mathcad software.

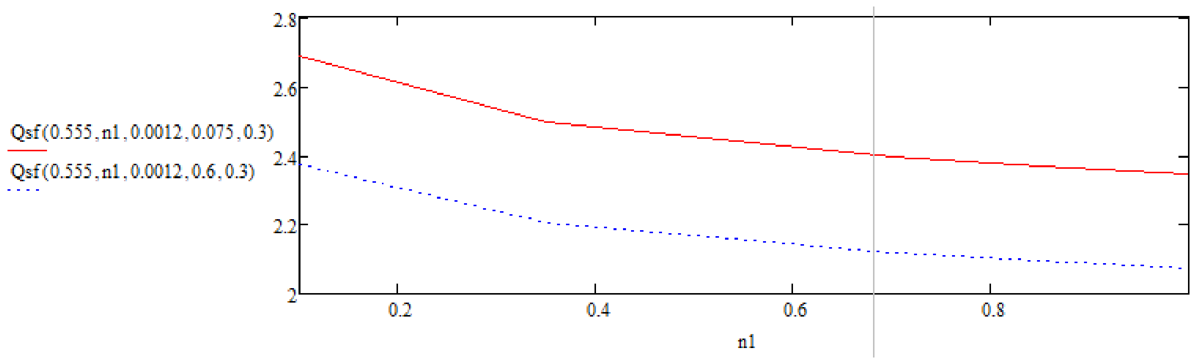


Fig.4 – Variation of the sorted seed mass (Qs) depending on the speed of the coil (n_1) and the advance speed of the grains in the helical movement (V_M)

Qsf --- Variation of the sorted seed mass depending on the speed of the coil, when considering the minimum advance speed of the grains in the helical movement; Qsf - Variation of the sorted seed mass depending on the speed of the coil, when considering the maximum advance speed of the grains in the helical movement

From Fig 4, can be deduced that when modelling the results on the dependence of speed of the coil (n1) and the advance speed of the grains in the helical movement (V_M), the sorted seed mass will have a downward curve. A short length of the sieve was imposed to the equipment, which is very common in practice. It is observed that for small sieves, the increase of the speed of the coil will produce a decrease of the efficiency of the equipment, because the row material will not have time to separate efficiently. The higher will be the speed of the grains in the helical movement, the lower the sieve efficiency will be, therefore it is necessary to introduce some improvements to the sieve internal blades in order to be able to keep the seeds in process for a longer time, and to have a more pronounced mixture of the seeds.

The decrease also occurs due to the high weight of the wheat grains compared to the other elements in the mixture. Wheat grains will fall gravitationally on the surface of the sieve, not allowing the stalks, straw or other seeds to penetrate through the external perforations of the sieve.

The second simulation considered also Eq. 3, and calculated the variation of the sorted seed mass (Qs), depending on the speed of the coil (n_1) and the distance between the elements of the coil, designed to drive the wheat grains inside the sieve (De). It has been considered that the speed of the coil (n_1) varies in the range 0.2-0.8 (s^{-1}), the feed rate of the material subjected to sorting (V_M) being 0.0075 m/s, using the distance between coil elements (De) of 0.0012 – 0.00575 m for pre-sorting seeds by their dimension, a specific load (q) of 0.555 kg/s^3, and the length of the sieve (l) of 0.3 m. Thus, the variation curves of the sorted seed mass Qs, in kg are obtained, as shown in Fig. 5.

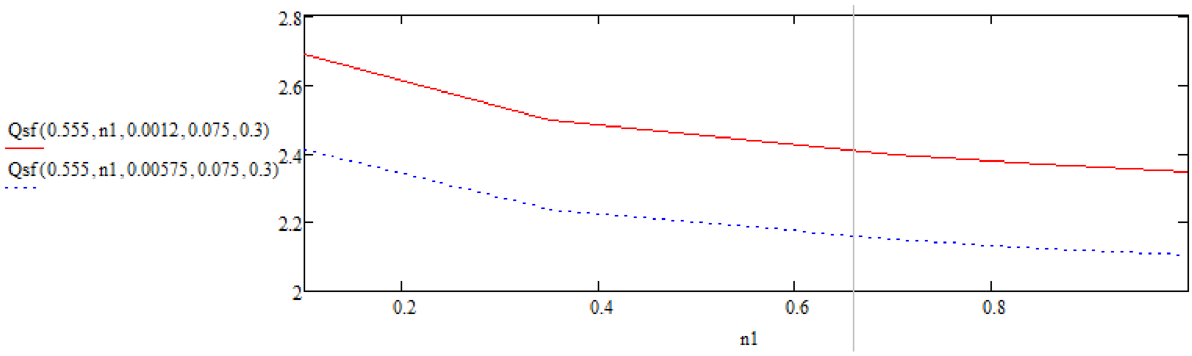


Fig. 5 – Variation of the sorted seed mass (Qs) depending on the speed of the coil ($n1$) and the distance between the blades of the coil driving grain inside the sieve (De)

Qsf --- Variation of the sorted seed mass depending on the speed of the coil, when considering the minimum distance between the coil blades;
Qsf - - - Variation of the sorted seed mass depending on the speed of the coil, when considering the maximum distance between the coil blades;

In this case can be observed that the distance between the blades of the coil is inversely proportional to the efficiency. Therefore, for small sieve sizes, a small distance between the blades is needed to increase the efficiency of the equipment. A small distance between the blades will generate the installation of several more blades on the coil, so a greater mixing will occur. However, this is not enough to achieve increased efficiency for small sieves, the general tendency being to decrease the efficiency with the increase of the speed.

Following the mathematical modelling process, the sieve construction was optimized with a new inner coil design, which would increase the equipment efficiency. The new technical solution depicted in Fig 6, enhances the separation process through a more intense breaking of the seed immobile nucleus. This will cause the layers in the centre of the immobile nucleus to come into more frequent contact with the surface of the cylindrical sieve, the contaminated seeds being excluded much faster from the flow.

The subassembly has a complex construction, being made up of a perforated steel sheet on the outside *(1)* having perforations with the size of 2.24 x 20 mm, a rotating axis *(2)* which is attached to the drive gear separately from the perforated cylindrical surface, the rotating coil blades *(3)*; while distance between the sieve and the coil *(4)*, have been set to d=1 mm. The size between the sieve and the coil have been chosen to be 1 mm so that the coil blades could lift the wheat grains that have larger sizes, while smaller contaminants will remain on the sieve surface, easily coming out through perforations. On other subassembly designs the wheat grains tend to block the sieve holes, due to their higher masses and volumes, thus making the separation more difficult. The new designed coil will overcome this problem, having a continuous action of removing the grains from the surface of the sieve and improving the separation.

In figure 7, the sieve *(1)* and the inner coil can be seen separately. It can be observed that the coil blades are designed so that they can be easily customized, which involves fastening the coil with screws, and not by welding. Thus, the blades are fastened through a perforated bushing on the axis of the coil *(2)* with 6 mm screws *(3)*, while the wing blades are fastened with 4 mm screws *(4)*.

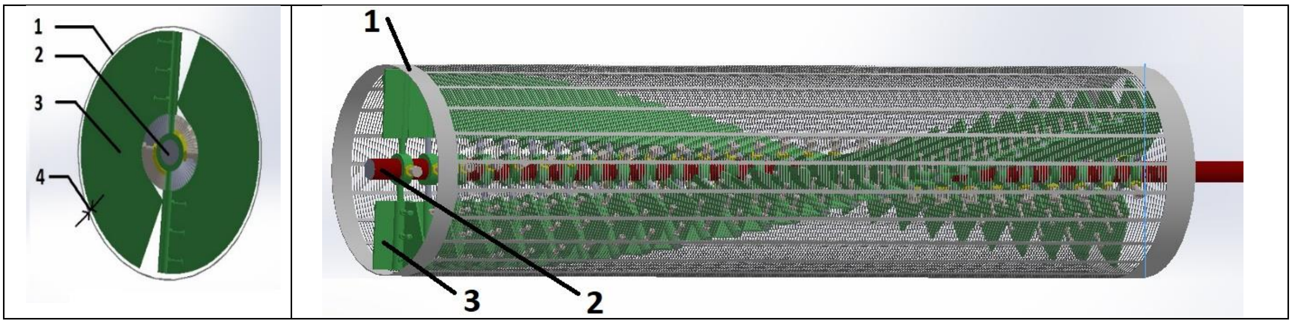


Fig. 6 – Overview of the new proposed subassembly, made of a sieve and a helical coil with the customizable blade angle of attack set to 45 degrees

1 – the sieve having perforations with size 2.24 x 20 mm.; 2 – the axis of the rotating coil; 3 - rotating coil blades; 4 - distance between the sieve and the coil, d= 1 mm

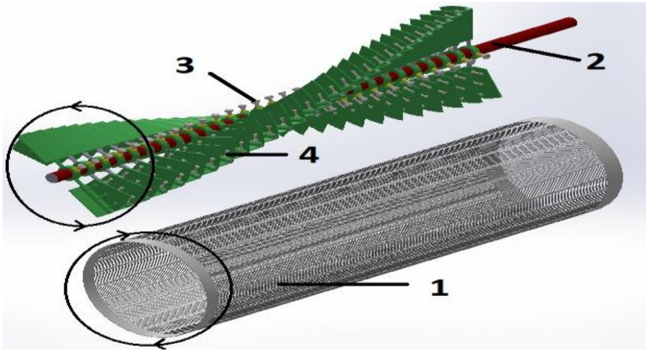


Fig.7 – Driving assembly, designed to run in the opposite direction of the sieve and the coil increasing the agitation level of wheat grains

1– the sieve; 2 - axis of the coil; 3 – fastening the blades through a perforated bushing on the axis of the coil; 4 – fastening the wing blade.

The detailed blades of the newly designed coil are shown in Fig 8. The coil has a high level of versatility and can adjust the rotation pitch and blade angle, to modify the equipment in case of large variations in contaminant levels, or large variations in humidity, to maintain efficiency at high levels regardless of the row material introduced. Therefore, with the fastening screws *(1)* the rotation of the blades on the coil axis through a bushing *(2)* can be adjusted, being able to vary the winding of the coil, and with the fastening screws *(3)* can vary the angle of attack of the blades (*4)*.

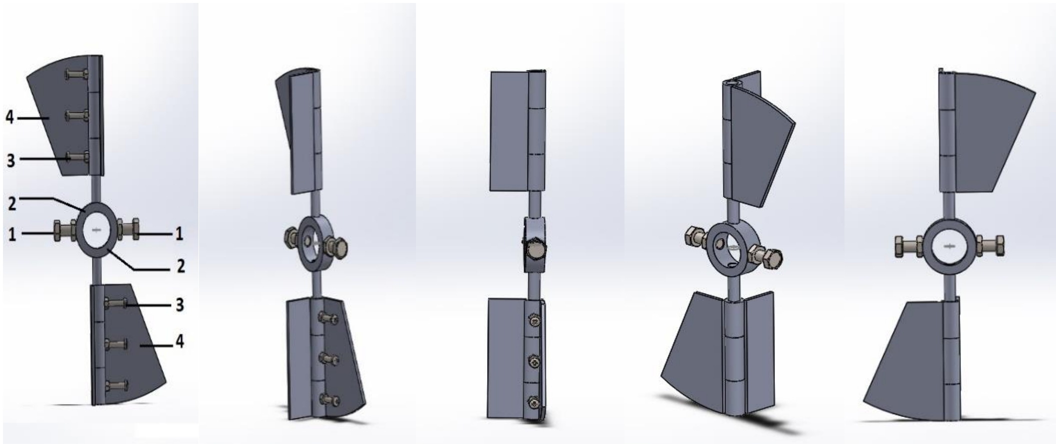


Fig. 8 – The subassembly blades installed on the coil axis, having the role of breaking the immobile nucleus

1– fastening screws for attaching the blade to the coil axis; 2 - bushing; 3 - fastening screws to vary the winding of the coil; 4 – wing blade

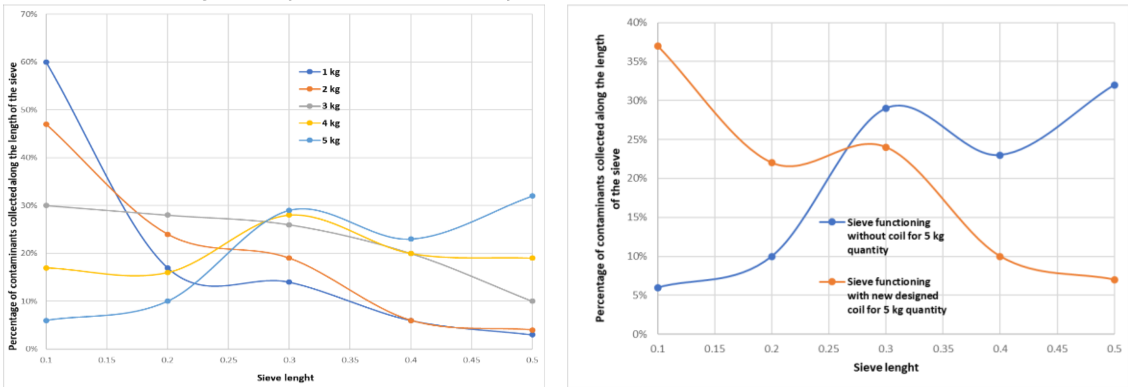
This technical solution further improves the breakage of any conglomerations of contaminants which adheres to wheat seeds, which are normally difficult to separate, having a more aggressive action on the row material being processed. This translates into a better separation of contaminants and a higher level of quality, because the wheat will dissociate from conglomerations reaching the separation tray.

An element of novelty is the possibility to change the pitch of the coil and the angle of the blades. The need to modify these elements comes from the different qualities of processed material, the coil pitch influencing the speed of the material crossing through the cylindrical sieve, while the positioning of the blades influences the mixing of the material in order to maximize the contact with the walls of the sieve.

Specially designed blades allow setting various inclinations facilitating the release from the sieve of heavier particles and is working in conjunction with the distance between the sieve and the coil of 1 mm, the subassembly will have a more pronounced action in taking over the large particles that would block the sieve holes. Lifting large particles allows smaller particles to come in contact with the sieve surface and pass through its holes, in the contaminant collection trays.

The coil drive will be oriented in the opposite direction to the sieve direction. By rotating the coil in the opposite direction to the rotating sieve, it will also rotate in the opposite direction to the seed mass, creating agitation, vigorously mixing the seed mixture, and making the seeds from the immobile nucleus reach the sieve surface easier. The process is also positively influenced by the special construction of the coil, the customizable angle making the process more efficient and adaptable.

The distribution of seeds on the surface of the sieve is a very important indicator for evaluating separation process, because it shows how the sieve changes its performances when varying some important parameters. The experimental results are obtained on an equipment that has no technological changes inside the sieve. The paper analysed theoretically (using mathematical modelling) which would be the best constructive solutions that can be adopted to the interior of the sieve, in order to solve some of the problems identified when working with cylindrical wheat separators.



a) Distribution of contaminants collected on the sieve length, by monitoring the collection trays found under the separator sieve (0.1 m - 0.5 m), for increasing amounts of input material (1-5 kg)

b) The distribution of contaminants collected on the sieve length for a quantity of 5 kg of input material; comparison between the sieve functioning with and without the new designed coil

Fig. 9 - Distribution of contaminants collected on the sieve length

By varying the angle of inclination, the sieve speed and taking as constant the level of contamination, to a fix value of 10% from the total mass of material introduced for processing, and taking the volumetric mass of the seeds of 718 kg/m^3, we can measure the distribution of contaminants collected along the length of the sieve. The quantity of contaminants collected in each of the collection trays has been weighed, subsequently calculating the percentage gathered on each of the trays.

Several rotational speeds, sieve inclinations and types of contaminants were analysed for 1 kg, 2 kg, 3 kg, 4 kg and 5 kg of input material, the average results are shown in Figure 9a. It can be observed that on small input material quantities, the separation occurs in the anterior third of the sieve length (more than 90%). Once the quantity of input material increases to 5 kg, the separation is achieved in the last segments of the sieve length. The large amounts of contaminant collected on the last sieve segments indicates that the process efficiency decreases abruptly for quantities of material over 5 kg, therefore the separation is no longer carried out efficiently on the entire surface of the sieve and some of the contaminants are escaping into the selected wheat seeds. Figure 9b shows the estimated efficiency improvement of the wheat separator when using the new designed coil installed in the rotating cylindrical sieve, according to the mathematical models, for the processing quantity of 5 kg material input.

The analysis shows that the sieve functioning with new designed coil becomes more efficient, having the possibility of increasing the amount of 5 kg of material input, thus exceeding the limitations of the previous separator model.

Figure 10 shows all the new designed elements installed on a rotary equipment for separating contaminants from wheat, consisting of: (*1)* - sieve body which adjusts the height and stabilizes the equipment; (*2)* - sieve drive module in the opposite direction to the coil; (*3)* - inner helical coil; (*4)* - feeding hopper; (*5)* - support for collection trays; (*6)* - collection trays shutter; (*7)* - horizontal collector chamber; (*8)* - vertical collector chambers; (*9)* - motor drive group; (*10)* - joint; (*11)* - sieve angle adjustment screw; (*12)* - sieve cleaning brush which removes contaminants from sieve perforations.

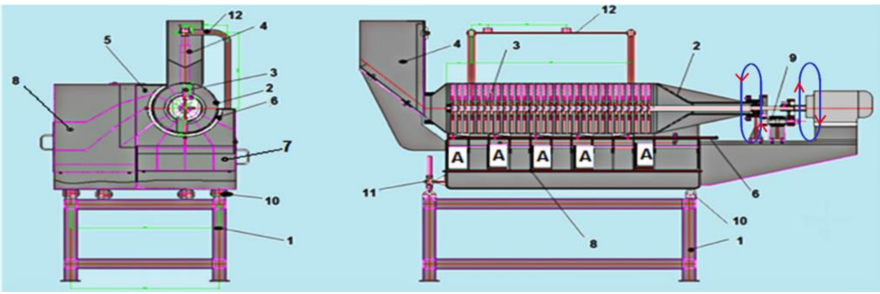


Fig. 10 - Representation of the newly designed subassembly installation in a cylindrical rotary separator
1- sieve body; 2- sieve drive module in the opposite direction to the coil; 3 - inner helical coil; 4 - feeding hopper; 5 - support for collection trays; 6 - collection trays shutter; 7 - horizontal collecting chamber; 8 - vertical collecting chambers; 9 - motor drive group; 10 - joint; 11 - sieve angle adjustment screw; 12 - sieve cleaning brush.

Vertical collecting chambers *(8)* are designed to determine the distribution of weights of foreign bodies along the length of the cylindrical sieve, in horizontal and angular plane. This is a very good adaptation to evaluate the capabilities of the equipment and is very useful to customize its rotating speed according to the degree of contamination. For example, if the row material is less contaminated, the operator will notice that residues will be collected only in the first chambers, while the last chambers will remain empty. Therefore, it will be possible to increase the amount of material introduced for processing or the processing speed of the equipment.

These collecting chambers can also be handful if the equipment is used in the evaluation of the harvested material quality, by the farmer. The quality evaluation is performed by entering a weighted quantity of wheat, and operating the equipment for 10 minutes. When collecting the trays, the contaminants that are easy to extract will be found in the first chambers, while those difficult to extract in the chambers at the end of the flow.

CONCLUSIONS

Our goal was to benefit as much as possible from the main advantage given by cylindrical separators, namely aggressive treatment of wheat, generated by the sieve rotation. From our theoretical and practical observations, it can be concluded that in the case of highly contaminated seed mixtures, the rotational movement of the sieve is not sufficient to achieve an efficient separation. If this shortcoming is solved by increasing the length of the sieve, then it would result in a too voluminous equipment, which is not desirable in industry fluxes. In addition, we wanted to raise the amount of row material that is introduced for cleaning into the feeder, for an increased efficiency of the equipment. We could not do this just by increasing the speed of rotation because there are limitations in this respect: on the one hand because it would speed up the movement of the seed mass towards evacuation and on the other hand because exceeding the sieve speed above a calculated critical velocity, it will lead to the seed adherence to the inner surface of the cylindrical sieve and the separation process will not take place in a proper manner.

The special subassembly designed consisting from a sieve and a novel helical coil, allows increasing the speed and introducing more material into the equipment, because a much more intense mixing process takes place. Taking into consideration the case of the equipment with a short sieve, we analysed both the main theoretical operating parameters and the practical evaluation of a pilot testing equipment which perfectly reproduces the operation of a classical industrial equipment.

The main novelty elements of the subassembly, consist in the special shape of the coil that improves the separation process, in the length of the coil blades near the surface of the sieve that facilitate the mixing. The mixing is also influenced by the angles associated with the sieve blades as well as the special designed shape. The possibility to make changes to the inner coil by varying the pitch or angle of inclination of the blades gives it a higher level of versatility depending on the degree of contamination of the inserted material.

In order to have an improved effect on breaking the conglomerations of contamination seeds/sticks/straws/leaf/dirt attached to the wheat seeds due to the intense movement, but without increasing the dimensions of the cylindrical sieve, we have introduced a direction of rotation of the coil opposite to that of the sieve. These changes to the equipment are estimated to bring a 15% improvement in operation by increasing the amount of processed material, depending on the wheat quality.

ACKNOWLEDGEMENT

The work was supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI - UEFISCDI project number PN-III-P1-1.2-PCCDI-2017-0659 / No.11 PCCDI/2018, within PNCDI III and a grant of the Romanian Education and Research Ministry, through Programme 1 – Development of the national research-development system, subprogramme 1.2 – Institutional performance – Projects for financing excellence in RDI, contract no. 16PFE.

REFERENCES

[1] Badretdinov I., Mudarisov S., Lukmanov R., Ibragimov R., Permyakov V., Tuktaro M., (2020), Mathematical modeling and study of the grain cleaning machine sieve frame operation. *INMATEH - Agricultural Engineering*, 60(1), pp. 19-28.

[2] Bracacescu C., Gageanu I., Popescu S., Selvi K.C., Ondokuz M., (2016), Researches concerning impurities separation process from mass of cereal seeds using vibrating sieves in air flow currents. *Conference: 15th International Scientific Conference on Engineering for Rural Development, Jelgava, Latvia,* http://tf.llu.lv/conference/proceedings2016/Papers/N066.pdf

[3] Căsăndroiu T., (1993), *Equipment for primary processing and storage of agricultural products (Utilaje pentru prelucrarea primara si pastrarea produselor agricole).* University Politehnica of Bucharest Romania;

[4] Jianbo, Y., Chongyou, W., Hua, L., Xindan Q., Xingxing, X., Xinxin, S., (2018), Movement rules and screening characteristics of rice-threshed mixture separation through a cylinder sieve. *Computers and Electronics in Agriculture,* 154, pp. 320-329. https://doi.org/10.1016/j.compag.2018.09.012

[5] Krasnicenko A.V., (1964), *Agricultural Machinery Manufacturer's Manual*, Vol.2 (translated from Russian). Technical Publishing House, Bucharest / Romania.

[6] Krzysiak Z., Samociuk W., Zarajczyk J., Beer–Lech K., Bartnik G., Kaliniewicz Z., Dziki D., (2020), Effect of Sieve Unit Inclination Angle in a Rotary Cleaning Device for Barley Grain. *Transactions of the ASABE.* 63(3), pp. 609-618. https://doi.org/10.13031/trans.13575;

[7] Naumenko M., Sokol S., Filipenko D., Guridova V., Kharytonov M.M., (2018), Numeric model of the grain mixture flow in a cylindrical sieve which revolves around the inclined axis, *INMATEH - Agricultural Engineering,* Vol.56, No.3, pp. 67-74, ref.19. http://oaji.net/articles/2019/1672-1546466819.pdf;

[8] Panturu D., Birsan I.G., (1997). *Calculation and construction of equipment in the milling industry, (Calculul si constructia utilajelor din industria moraritului),* Technical Publishing House, Bucharest / Romania.

[9] Paun A., Stroescu G., Visan A.L., Olan M., Zaica A., Moiceanu G., (2018), Researches regarding the optimization of impurities removal technology from the cereal and industrial plant seeds for establishing ecological crops, *INMATEH - Agricultural Engineering,* 56(3), pp.83-90;

[10] Shi X., Qi X., Wu C., Li H., Yuan J., (2018), Screening characteristics and parameter optimization of threshed rape mixture separation through a cylindrical sieve, *International Agricultural Engineering Journal,* 27(3) pp. 53-64;

[11] Yuan J., Wu C., Li H., Qi X., Xiao X., Shi X., (2018), Movement rules and screening characteristics of rice-threshed mixture separation through a cylinder sieve, *Computers and Electronics in Agriculture,* 154 pp. 320-329;

[12] Vasylkovskyi O., Vasylkovska K., Moroz S., Sviren M., Storozhyk L., (2019), The influence of basic parameters of separating conveyor operation on grain cleaning quality, *INMATEH - Agricultural Engineering*, 57(1), pp.63-70;

[13] Voicu G., Casandroiu T., Tarcolea C., (2008), Testing stochastic models for simulating the seeds separation process on the sieves of a cleaning system and a comparison with experimental data. *ACS - Agriculturae Conspectus Scientificus*, 73(2) pp.95-101.