The 4th International Conference
″Computational Mechanics
and Virtual Engineering″
COMEC 2011
20-22 OCTOBER 2011, Brasov, Romania

EXPERIMENTAL RESEARCHES ON THE INFLUENCE OF FUNCTIONAL PARAMETERS OF COMBINED SEPARATION INSTALLATIONS OF IMPURITIES FROM THE CEREAL SEEDS ON THE QUALITY INDICATORS OF SEPARATION PROCESS

Carmen BRACACESCU[1], Simion POPESCU[2]
[1]National Institute of Research - Development for Machines and Installations designed to Agriculture and Food Industry - INMA Bucharest, Romania, E-mail:carmenbraca@yahoo.com
[2]Transylvania University of Braşov, Romania, E-mail: simipop38@yahoo.com

Abstract: *The paper presents the experimental installation, the methodology and measuring apparatus used for experimental research of qualitative indexes of impurities separation out of grain seeds for combined separating systems (according to specific mass and aerodynamic properties of seeds). The experimental installation used was composed of a gravity separator with mechanical shaker with unbalanced masses (mounted on the platform working surface) and an aspiration installation with fan. The experimental research has aimed at quantitative and qualitative influence on separation quality index of the following operating parameters: material flow rate of shaking separator, the air flow of aspiration installation, tilting work surface, work surface oscillation amplitude. Based on data obtained by measurements and qualitative indicators the separating process indexes have been determined, namely: degree of impurities separation, degree of good seeds loss),as well as, the index of technological effect for different types of combinations of separation installation parameters.*
Keywords: *cereal seeds, cleaning, specific mass separation, shaker with unbalanced masses, aerodynamic separation, aspiration installation, index of quality separation*

1. INTRODUCTION

The cereals used as raw material for milling represent a heterogeneous mass consisting of basic culture grains (which are to be milled) and foreign bodies (impurities). Therefore, before being milled, the graina are subjected to cleaning operations aiming mainly the elimination of foreign bodies from the mass of seeds. The main properties that underlie the separation of impurities are: the difference in shape and size, the difference in specific mass (density), aerodynamic properties and magnetic properties.

Depending on the principle of separation and the type of impurities is used a wide range of technical equipment and installations for carrying out the separation of impurities. To reduce the number of technical equipment and implicitly of technological spaces, the modern milling units performing use complex installations carrying out the separation by combined principles, the most used following the specific mass difference being the ones and aerodynamic properties of various components of seed mixtures. The most technical equipment used of this type are the aspiring vibro separators.

The working process diagram of a combined equipment using two principles of separation (difference in specific weight and aerodynamic properties) for impurities in the grain mass is shown in Figure 1. The mixture of cereals (grains and impurities) to be separated is introduced in the feeding area 3, on the working surface (tilt) of oscillating platform 1. Due to the effect of platform work surface vibration and combined with the action air currents 4, the mass of product stratify on the work surface. The particles of impurities with specific mass greater than that of cereal seeds remain in contact with the inclined surface of the platform, while the light and very light particles sorts in upper layers. Under the action of air flow aspirated 4 the seeds are fluidised and float above the work surface, which do not come in permanent contact, flowing on its inclined plane (downstream) to the discharge ports, placed at the lower end of the separator. Due to amplitude and frequency of surface separation oscillations (working) 1, a process of transportation is achieved through heavy particles 5 in contact with oscillating platform are transported (moved) to the upper end (upstream) of the inclined surface 5. The dust, chaff and other light impurities are sucked and transported through the pipeline of a suction plant (with fan), reaching in the final in a cyclone, carrying out the aerodynamic separation and decantation of the aspirated material.

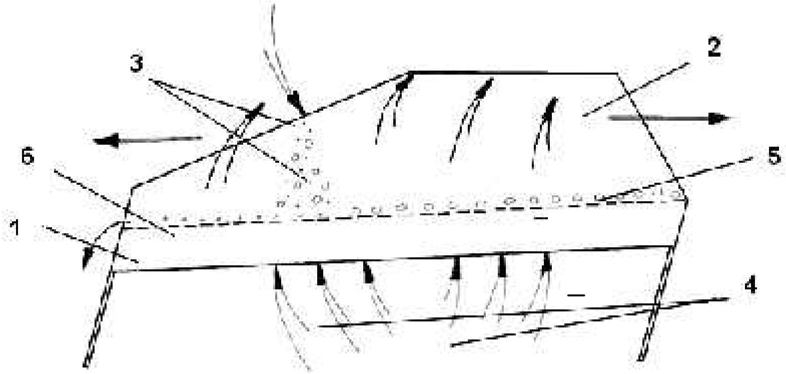

Figure 1. The working diagram of the gravitational separator connected to the suction system: 1 - working platform, 2 suction room (hood), 3 - product supplying, 4 - aspirated air currents, 5-heavy impurities particles, 6-cleaned product

Figure 2 shows the functional diagram of a separation device of impurities combined from the mass of grain, consisting of vibrating separator gravimetric 1 and a suction installation of light impurities (formed by suction fan 2, cyclone 3 for separation and collecting elements of impurities 4)

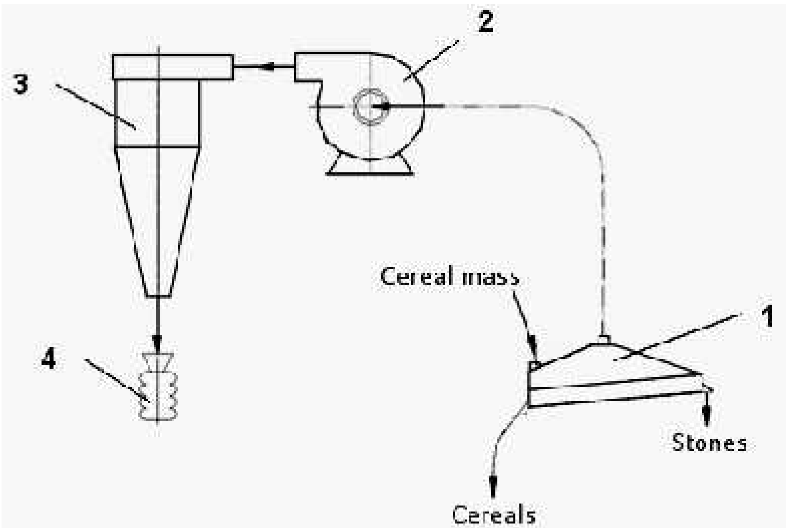

Figure 2. Functional scheme of the separation technical equipment used in the stand: 1 - gravimetric separator (densimetric separator) 2 - suction fan, 3 - cyclone, 4 - bags for light impurities and dust collection

The principle scheme of a vibratory separator operated with vibrators with unbalanced centrifugal masses is shown in Figure 3, being composed of vibrant mass 2 elastic suspended by a fix support and a vibratory mechanism (motovibrator) 1, generating vibration with rotating unbalanced masses, at which the resultant disturbing force is directed in a specific direction relative to the vibratory working surface.

For the analysis of solutions to optimize the separation processes of impurities from the cereal seeds at these types of separators it is necessary the experimental determination of the influence of of functional parameters (flow rate of material supply, air flow of the suction installation, direction of propagation of oscillations of the vibrating plane of the separator, tilt and oscillations amplitude of the working surface vibroseparator) on the quality indices of the separation process (degree of separation of impurities, the degree of loss of good seeds, the index of technological effect).

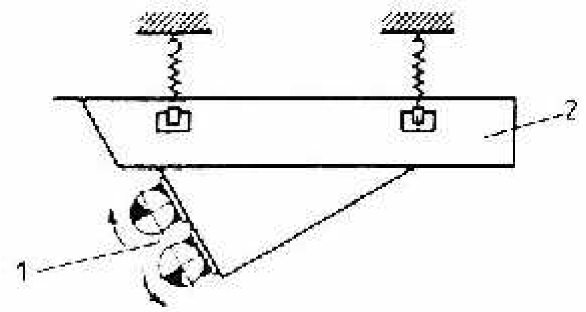

Figure 3. The principle scheme of a separator with vibratory platform operated by unbalanced centrifugal vibrating masses :
1 - vibrator with unbalanced centrifugal masses; 2 – vibratory suspended table (platform).

2. MATERIAL AND METHOD

In the following is presented the installation and the experimental determination research methodology used to determine the qualitative indices of the separation process of impurities from grain seeds in the case of combined separation systems (relative to the specific mass and the aerodynamic properties of seeds). Installation realised after the scheme in Figure 2, consists of the gravitational separator 1, model SP-00, realised at INMA Bucureşti (Figure 4), connected to a suction installation with air model IASP-0 composed of the ventilator 2 and the cyclone 3, realised at SC IMA SA Iasi./Romania.

Figure.4. General view of of the installation used in experimental research
1 - elevator; 2 - gravimetric separator; 3 - intensive vacuum separator; 4 - fan, 5 - dedusting cyclone; 6 - control and signaling panel

The main component parts of the gravitational separator SP-00 are shown in the constructive scheme in Figure 5. The method of adjusting the imbalance force acting on the shafts 3 of the driving electric motors of the vibrators unbalanced masses is given in Figure 5. Adjustments are achieved by mounting of plates 1 and 2 in different relative positions , of semicircular shape, the size of centrifugal force developed for different coverage degrees of the plates surface being given in the graph at the bottom of Figure 6.
To establish the influence of functional parameters of separation plant (flow rate supply with material of the separator, air flow rate of suction installation, inclination of platform of the vibrating working surface, oscillations amplitude of working surface) on indices of the impurities separation process (the degree of separation of impurities the degree of good seeds losses) and the index of technological effect.

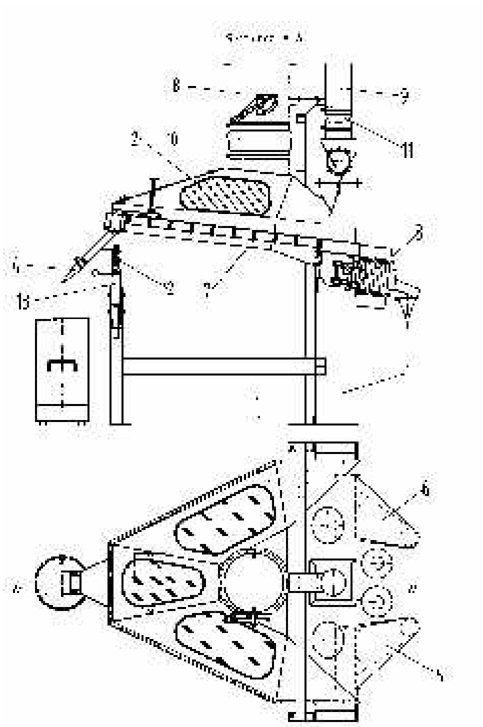

Figure 5. Constructive scheme of gravitational separator SP-00
1 - framework for support; 2 - vibrant housing, 3 - motovibrator for acting the platform of working surface; 4, 10 and 11 - elastic sleeves; 5 and 6 - pipes for exhausting of cleaned product; 7 - working surface from wire fabric; 8 - air-intake pipe; 9 - pipeline for supplying with product; 12 - elastic support system (springs) of the vibrating platform; 13 - screw device for adjusting the angle of inclination of the platform working surface.

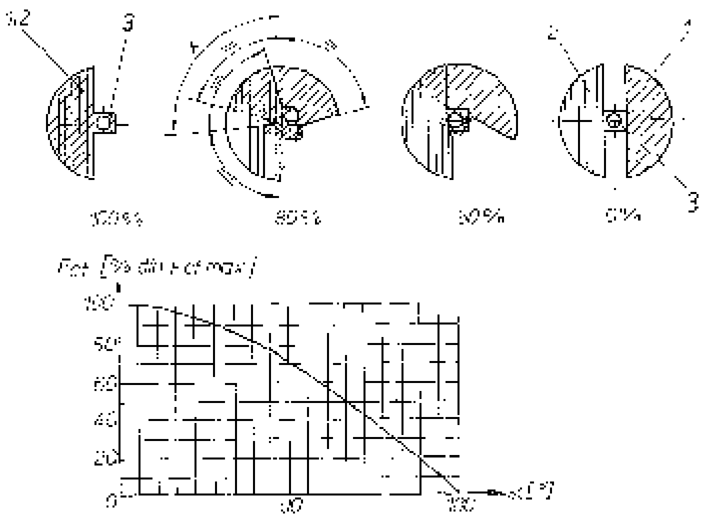

Figure 6. Adjustment scheme of imbalance forces of the masses of centrifugal excitation control forces achieved by the motovibrators of the vibrating platform of separator:
1, 2 - control plates; 3 - drive shaft of the unbalanced masses

Experimental measurements were made in different versions, summarized played in the scheme of the program in Figure 7. The material used at experimental researches was the wheat (as seeds), crop production in 2010, obtained from experimental plots of INMA Bucharest. This material was first introduced in the intensive vacuum separator, being subjected to the operation of separation by size

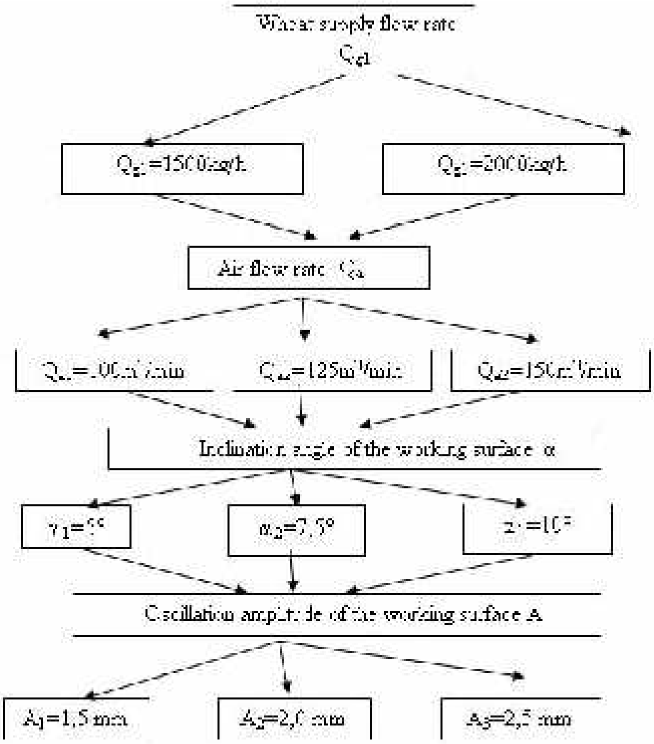

Figure 7. The scheme of experimental test program

For experimental measurements were used measurement devices and / or registration of the following sizes (parameters): masses of products and impurities in the separation process; inclination angle respect to the horizontal of the working surface of the separator (vibrating sieve); air flow rate of the suction installation by determining the velocity of air currents in the suction pipe; oscillation amplitude of the working surface; frequency of oscillation of the electro-vibrators, by determining their rotation speed; power onsumption of electro-vibrating system of the separator; humidity and temperature of processed product.The air flow rate from suction pipe was determined indirectly by calculation by measuring the air velocity v with the anemometer Testovent 400.

The location mode of the the measuring instruments at the experimental stand is shown in Figure 8.

Figure 8. The location mode of measuring devices and adjustment areas
1 - displacement transducer; 2 - counterweights of vibrator; 3 – mechanism with screw;
4 - suction pipe; 5 - amplification and data acquisition module; 6 - laptop

On entry and exit of wheat in the separator and at evacuation of impurities in the process of separation were determined the following parameters: humidity and hectoliter mass of wheat grains at the entrance in the separator; hectoliter mass of the resulting product in the process of separation; impurities content of wheat at the entry and exit from separator.

Table 1. Functional operating parameters of the stand

Crt. iss.	Determined parameter	U.M.	Parameter value determined at tests
1.	Material supply flow rate (test versions)	kg/h	1500; 2000
2.	Sample mass	kg	1000
3.	Duration of test	s	2400; 1800
4.	The quality of the processed product at the entry into machine - humidity; - hectolitric mass; - impurities	 % Kg/hl %	 11.92 78.7 2.41; 2.47
5.	the suction air flow rates of the installation (test versions)	m^3/min	100; 125; 150
6.	air speed in the suction pipe at air flow rates of the suction installation (test versions)	m/s	17.36; 21.7; 26.04
7.	Power absorbed by the of the gravitational separator	kW	0.7
8.	Power absorbed by of the suction installation	kW	7.5
9.	Total absorbed power	kW	8.2
10.	Specific electricity consumption of the gravimetric separator	kWh/kg	0.00045
11.	Specific electricity consumption of the stand (separator and suction installation)	kWh/kg	0.0046

For the calculation of the technological effect index were determined by weighing and calculation for the following sizes, reported to 1,000 kg of wheat processed by the separator: total quantity of impurities separated, kg; the quantity of eliminated stones, kg; the quantity of other impurities eliminated (seeds of other nature including broken, non-eliminated light seeds, soil, etc.), kg; the quantity of lost good seeds, kg.

The coefficient of loss of good seeds C_{ps} is calculated with the relation:

$$C_{ps} = (m / M) \cdot 100 \quad [\%] \tag{1}$$

where: m is the good seeds mass which are found at the exit from equipment in the quantity of total impurities eliminated; M- good seeds mass at yhe entry into equipment.

The index of technological effect E_{cs} represents the percentage of foreign bodies (impurities) eliminated from the mass of processed product and is determined with the relation:

$$E_{cs} = \left[(C_{csi} - C_{cse}) / C_{csi} \right] \bullet 100 \quad [\%] \tag{2}$$

where: C_{csi} is content foreign bodies (impurities) at the entrance of the material in equipment, %

C_{cse}- content foreign bodies (impurities) at evacuation of material from equipment, %

The quantity of electricity W consumed by motovibrators is calculated by the relation:

$$W = (P_a \cdot t) / 3600 \quad [\text{kWh}] \tag{3}$$

where P_a is the power absorbed by the pair of motovibrators (kW), measured with the phase and frequency analyzer model CA 8334; t - operating time at tests (s).

The working capacity Q of the gravitational separator was determined by calculating with the relation:

$$Q = 3600 \frac{m}{t} \quad [\text{kg/h}] \tag{4}$$

where: m is the initital material mass (m=1000 kg); t - time required for experimental determination, s.

Specific electricity consumption q represents the amount of electricity (in kWh) consumed to process one kilogram of product and was determined by calculation with the following formula:

$$q = \frac{P_u}{Q \cdot \eta_{me}} \quad [\text{kWh/kg}] \tag{5}$$

where: P_u is the the effective power of the machine, kW; Q- the flow rate of processed product, kg/h; η_{me}- actuation yield.

The values resulting from processing determined parameters are mentioned in Table 1.

3. RESULTS AND DISCUSSIONS

By processing the obtained experimental data were made synthetic tables with the parameters determined experimentally for variants established by experimental research program. For an intuitive analysis of the influence of various constructive and functional parameters of the combined separation installation on the global technological index values E_{CS} were drawn graphics expressing the following technological the dependency of the index values of functional parameters (adjustment) of the separator: the supplying flow rate with product subjected to processing (wheat), the air flow rate of the suction installation, the angle of inclination respect to the horizontal working surface of the separator and the oscillation amplitude of the separator working surface. Below will be presented for illustration, some representative graphics [1].

The variation of the technological index values E_{CS} depending on the supplying flow rate of with product (wheat) Q_p, corresponding to an air flow rate of the suction installation Q_a=100 m^3/min, for different inclination angles α_k and amplitudes of the oscillations A_k of the separator working surface.

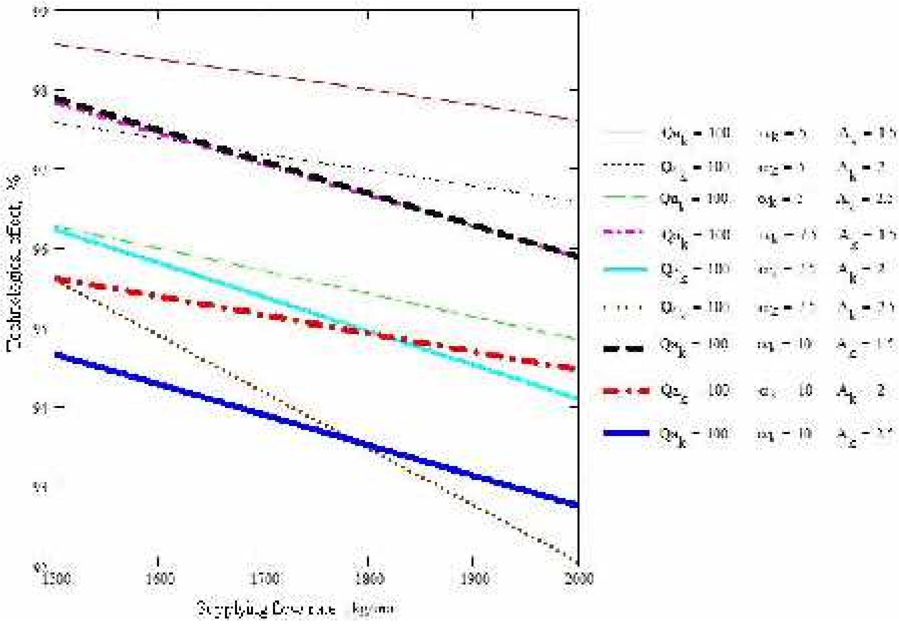

Figure .9. Variation of the values of technological effect index E_{CS} depending on the supplying flow rate with material (wheat) Q_g at suction installation flow rate of Q_a=100 m^3/min, for the following adjustment parameters: inclination angle of the working surface α= 5; 7, 5; 10° and working surface amplitude A= 1.5; 2; 2.5 mm

Influence of the air flow rate in the suction line Q_a on the value of technological effect index E_{CS} at a supplying flow rate with material (wheat) Q_g=2000 kg/h for different inclination angles α_k and amplitudes A_k of oscillations of working surface of the separator is shown in Figure 10.

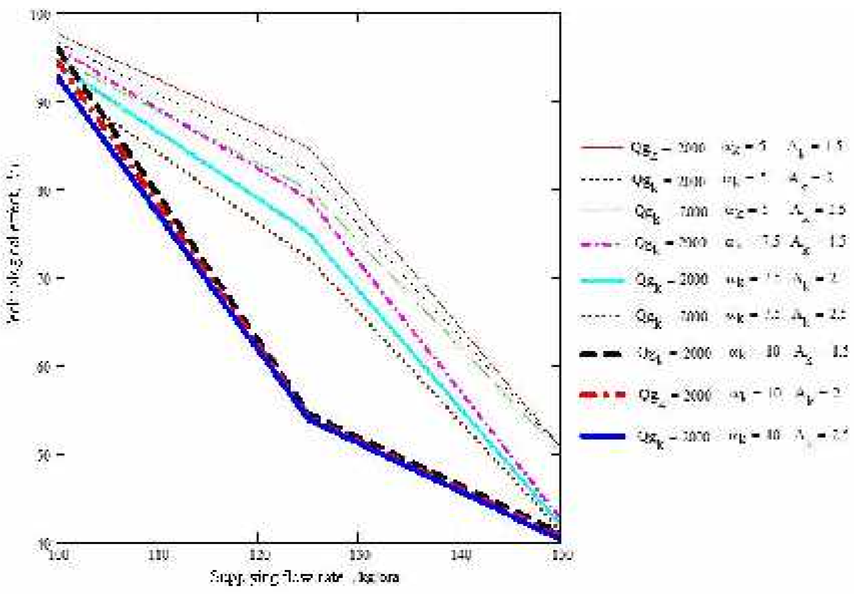

Figure10. Variation of the values of technological effect index E_{CS} depending on the air flow rate Q_a for the suppling flow rate with material (wheat) Q_g=2000 kg/h for the following adjustment parameters: inclination angle of the working surface α= 5; 7, 5; 10° and working surface amplitude A= 1.5; 2; 2.5 mm

In Figure 11 is represented the technological effect index variation E_{CS} depending on the angle of working surface α of separator at a supplying flow rate with material Q_g=2000 kg/ *for* the following adjustment parameters: inclination angle α and amplitude A_k working surface oscillations.

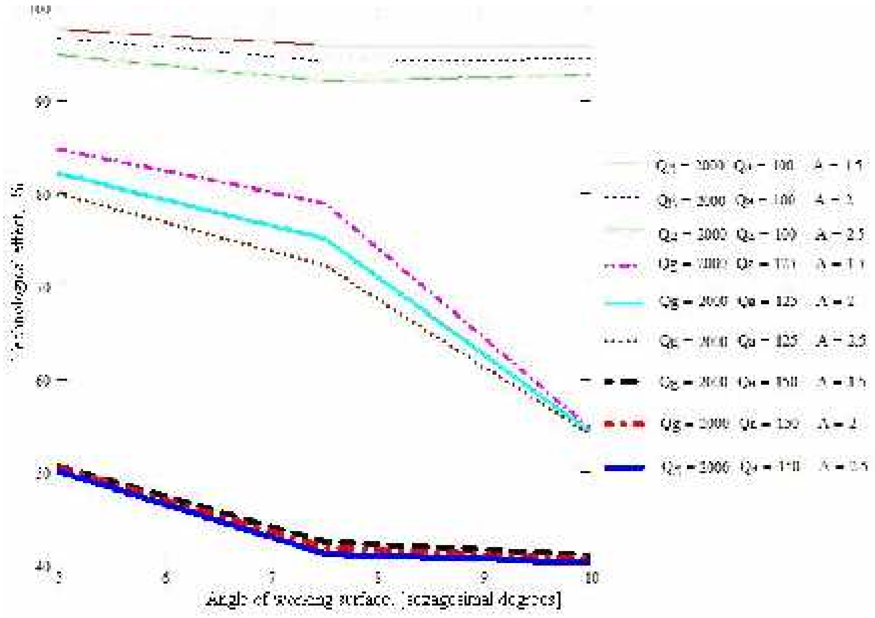

Figure 11. Variation of the values of technological effect index E_{CS} depending on the angle of the working surface α at the supplying flow rate with material Q_g=2000 kg/h, for the following adjustment parameters: air flow rate Q_a=100; 125;125 m^3/min and working surface amplitude A= 1.5; 2; 2.5 mm

Variation of technological effect E_{CS} with the amplitude A_k of oscillations of the working surface at the supplying flow rate with material Q_g=1500 kg/h, depending on air flow rate in the suction pipe Q_a and inclination angle of the working surface α is illustrated in Figure 12.

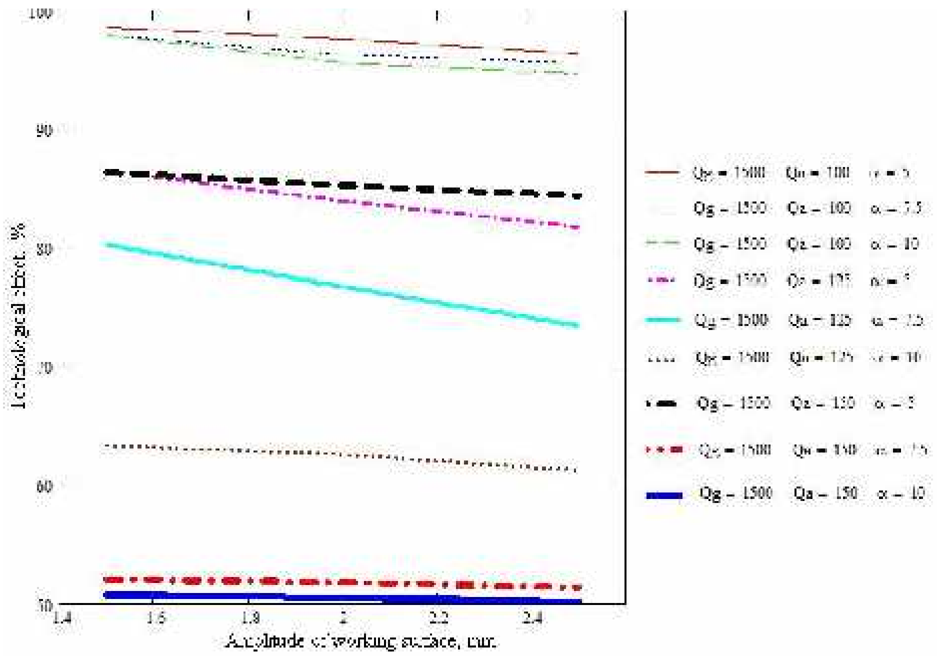

Figure 12. Variation of the values of technological effect index depending on the working surface amplitude A for the supplying air flow with material Q_g=1500 kg/h , for the following adjustment parameters: air flow rate Q_a=100; 125;125 m^3/min and inclination angle of the working surface α= 5; 7.5; 10°

Applying linear regression method at determined experimental data processing is obtained the technological effect function ET, as a function of the supplying flow rate with material (wheat) Q_g (in kg/h), flow rate air sucction Q_a

(m^3/min), angle α (in sexagesimal degrees) of inclination of the working surface and the amplitude of oscillation A (în mm), expressed by the relation [1]:

$$ET(Qg, Qa, \alpha, A) = -0.015892Qg - 0.848367Qa - 3.256444\alpha - 2.736111A + 237.645463 \quad (6)$$

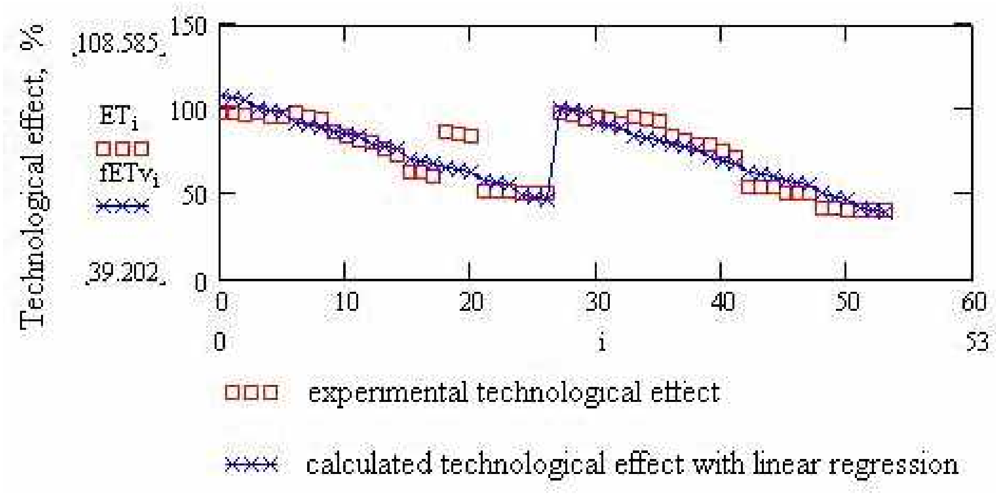

Figure13. Comparison of the experimental data with those obtained by linear regression at the determination of the technological effect index

It should be noted that equation (1) corresponds to units of measurement in which were given the results of experiments. At the transition to SI system, formula (1) get the following form:

$$ET(Qg, Qa, \alpha, A) = -57.210667Qg - 50.902Qa - 196.580523\alpha - 2736.111111A + 237.645463 \quad (7)$$

In the case of formula (6), the correlation between the experimental data and calculated data in the experimental points with the regression given by relation (8) has the value 0.932.
From the the graphical representation in Figure 13 of the formulas (6) and (7) result that the index of global technological effect decreases with the increase of the supplying flow rate with material, of the working surface angle, of the working surface amplitude and of the suction air flow rate.

CONCLUSIONS

From the analysis of data obtained by processing the experimental data revealed the following conclusions:

- the suction current introduced into the gravimetric separator favors the stratification of particles uniform dimensionally but with different specific weights, their movement on the surface of of the separator being possible even under the minimum impulses;
- the values of the effect of technological working index decrease with the increase of the supplying flow rate with material (wheat) of the separator, being more evident at low angles of inclination of the working surface (5^0) and at lower flow rates of air suction.
- the values of working technological effect index decrease with increasing of air flow rate of the suction installation in about . 83% of cases tested; in 17% of cases (where there is intervals of increase and decrease with increasing of air flow rate) variation of this index is neither monotonically increasing nor decreasing monotonically. The analysis the experimental data shows that 67% of cases opt for convex variations technological effect relative to the air flow rate, the remaining reflecting a concave variation.
- technological working effect index values have a monotone decreasing variation with angle of vibrant platform of working surface: 77.8% of the experimented cases shows that the dependency of technological effect to the working surface angle is nonlinear, the remaining showing a pronounced linearity closeness; 77,7 % from experiments highlight a convex curve of variation of the technological effect with the angle of working surface, the remaining reflecting a concave variance.
- within the experimented working range in the researches on stand showed that the index of the technological working effect had an approximately linear variation with the oscillation amplitude of the working platform surface. Overall there was a decrease in the technological effect index with increasing of amplitude of working surface; although the amount of separated heavy impurities is higher it is found an increase in mass of good seeds eliminated in the mass of impurities;
- The results obtained during the experimental researches reveal that the entire (stand) used consisting of gravitational separator model SP-00 and the suction installation model IASP-0 comply with the requirements in

terms of destination, of the purpose and functioning mode, of the possibilities for adjustment and servicing, working having a working capacity suitable to deposits from agricultural farms, cereal seed conditioning stations as well as technological flows from milling units.

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