A NEW THEORY REGARDING THE VEGETAL MATTER DISPLACEMENT ON SHAKER STRAW WALKERS DISPOSED ON TWO AXES AT CONVENTIONAL CEREAL HARVESTING COMBINES

O NOUĂ TEORIE PRIVIND DEPLASAREA VRAFULUI PE SCUTURĂTORUL CU CAI DISPUŞI PE DOUĂ AXE LA COMBINELE CONVENȚIONALE DE RECOLTAT CEREALE

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Abstract: *The conventional harvesting combines for cereal comprise a shaker aiming (straw walkers) to separate the seeds out of straws coming from the threshing apparatus. The working capacities of the straw walkers and implicitly of harvesting combine depend on the configuration and kinematics regime of shaker. Within the following paper a new theory of straw displacement on the shaker is presented. This theory is decisive for manufacturing a performing shaker.*

Rezumat: *Combinele convenționale de recoltat cereale au în componență un sistem de scuturare (scuturător) care separă semințele din vraful rezultat de la aparatul de treier. Capacitatea de lucru a sistemului de scuturare şi implicit a combinei de recoltat depinde de configurarea şi regimul cinematic al acestuia. Articolul prezintă o nouă teorie privind deplasarea vrafului pe scuturător. Această teorie este decisivă pentru construcția unui scuturător performant.*

***Key words*:** *harvesting combines, straw walkers shaker, new theory;*
***Cuvinte cheie*:** *combine de recoltat, scuturător, tehnologie nouă;*

INTRODUCTION

The cereal conventional harvesting machines (fig. 1) are made of two main parts: the header and the thresher.

The header is a combine equipment used at plant cutting and transport to the thresher. The principal working parts of header are the cutter, ear swinging device and spiral conveyor. The header elevator is a scraper conveyor able to ensure the header coupling to the thresher.

The combine thresher is aimed at plant threshing (detaching and separating the seeds from the ears), separating and cleaning the crop seeds from their straw parts (straw, chaff), the proper seeds from weeds and other impurities. The main working parts of thresher are the threshing apparatus, the shaking system (shaker) and the cleaning system. Other parts involved in technological flow are: the conveyor transporting non-threshed ears, the seed conveyor and the hopper.

The cereal conventional combines use straw shaker walkers disposed on two axles (fig. 2) having in view the shaker simple construction, technological efficiency and little power necessary for its diving and also the fact that this system does not harm the seeds.

At current conventional combines the straw walker shaker is formed of 4…6 shaking elements (walkers) and two crank shafts (axles) from which the rear one is used at shaker drive. The shaking elements comprise 4…11 cascades, 5...12 sieves of seeds separation out of the proper matter and are generally, in cross section in shape of chute. The chute has side walls with toothed edges (retaining elements) for retaining the proper matter on the shaking elements and its advancing towards the exhausting combine When the shaking elements are not endowed with collecting chutes, then a tilted flat surface is disposed under the shaker for leading the separated matter towards the combine oscillating plan.

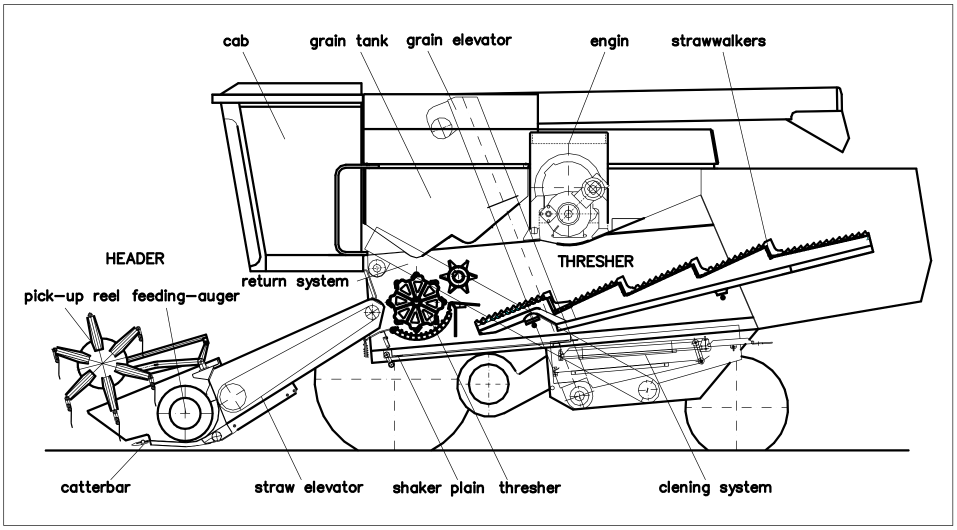

Figure 1. Main working parts of a cereal conventional harvesting machine

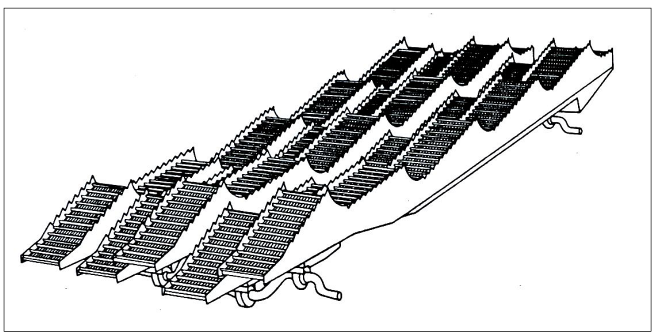

Figure 2. Straw walkers shaker disposed on two axles

The shaking elements (fig. 3) of straw walkers shaker perform a plane – parallel movement any point forming circles whose ray is equal with the ray of arrangement of shaker crank shaft levers. This movement produces two processes:

- the vegetal matter displacement towards the combine exhausting system;
- the separation of seeds.

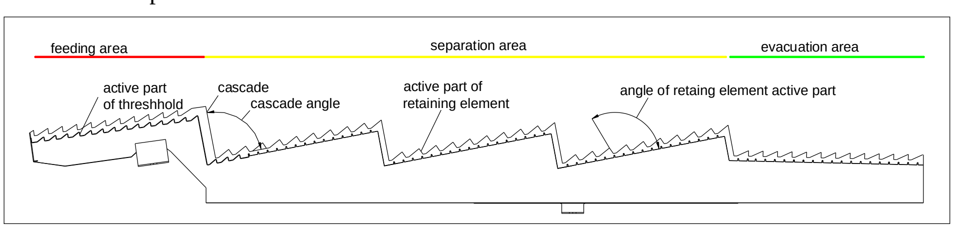

Figure 3. Representation of functional areas of shaking element endowed with four cascades and five sieves

The both processes are simultaneously performed on all functional areas, but one of them is predominant according to the respective area. Taking into account the preponderant process, the shaking elements have three functional areas:

- ***feeding area*** – where the matter resulting from the threshing apparatus is taken over by the shaking element;
- ***separation area*** – where the preponderant process is the separation of seeds from the respective matter;
- ***exhausting area*** - where the preponderant process is the removal of straws from the combine.

Aiming at the performing the shaking process, we can make the following appreciations regarding the displacement of the matter on the shaker:

a. the matter displacement on the shaker is determined by the shaker rotating speed, value of angles made by sieves with the horizontal and by cascade angle value and active part of retaining elements in comparison with sieves;
b. the vegetal matter displacement is principally due to cascades;
c. the vegetal matter displacement on shaker is performed depending on matter physical and mechanical characteristics (type of culture, length of straws, humidity, matter friction coefficient on shaking element surface);
d. the matter behaves as a deformable body, being characterized by an internal elasticity which is manifested by a series of compressions and expansions depending on shaking element's position. The matter elasticity increases when it contains a bigger quantity of large straws.

MATERIALS AND METHOD

According to the current theory, the displacement speed of vegetal matter on shaker straw walkers disposed on two axes depends on the shaker, rotating speed, ray of arrangement of crankpins on crank shafts an don the sieve angle in comparison with horizontal. But, the theory does not cover all the aspects regarding the matter displacement on the shaker, such as:

- the importance of cascades is not emphasized and the matter displacement on shaking element in their area is not studied;
- there is no a study regarding the influence of angles made by cascades, active part of retaining elements and sieve sill;
- there is no a methodology for the cascades' high calculus, for the active part of retaining elements' high and sieve sill;

Following those presented above, we propose a new theory regarding the matter displacement on a straw shaker with walkers on two axes. This theory adds to the factors above the angle made by cascades in comparison with sieves, as principal factor in defining the matter displacement on the shaker.

In figure 4 is shown the path of matter displacement which is in the separation area of a shaking element at a complete axle rotation for a cascade and active part of retaining elements which form a $90^0+\delta$ angle with the sieve.

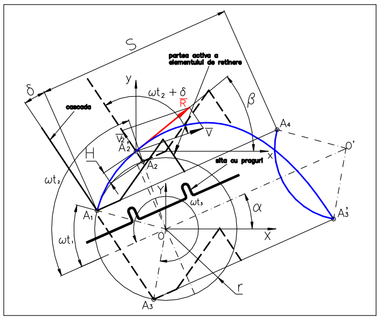

Figure 4. Path of matter displacement on separation area of a shaking element

The matter displacement path on a shaking element is determined by the relation:

$$\omega t_1 = \arcsin \frac{\cos(\alpha+\delta) + f\sin(\alpha+\delta) + f\sqrt{k^2\left(1+f^2\right) - \left[\cos(\alpha+\delta) + f\sin(\alpha+\delta)\right]^2}}{k\left(1+f^2\right)} - \delta; \quad (1)$$

where ωt_1 is the angle of crank shaft at which the matter begins to detach from the shaking element and to skip on the wall of cascade of retaining elements' active part;

α – sieve angle in comparison with the horizontal;

δ – angle of cascade and retaining elements' active part in comparison with the following sieve;

k – shaker cinematic regime $k = \omega^2 r / g$;

ω – angular speed of crank shaft;

r – ray of arrangement of crank shaft's crankpins;

g – gravitational acceleration;

f – friction coefficient of matter – shaking element.

If $\omega t_1 \geq 0$, it results:

$$\arcsin \frac{\cos(\alpha+\delta) + f\sin(\alpha+\delta) + f\sqrt{k^2\left(1+f^2\right) - \left[\cos(\alpha+\delta) + f\sin(\alpha+\delta)\right]^2}}{k\left(1+f^2\right)} \geq \delta; \quad (2)$$

The unequation result represents the maximum value of δ angle of cascade and retaining elements active part in comparison with the next sieve

$$\omega t_2 = 90^0 - \delta + \arcsin \frac{\sin(\alpha+\delta)}{k} \quad (3)$$

where ωt_2 is the crank shaft angle at which the vegetal matter jumps from the shaking element;

$$H = \frac{c_{(\delta)} r}{2}(\omega t_2 - \omega t_1) \quad (4)$$

where H is the matter displacement on cascade or retaining elements active part;

$c_{(\delta)}$ – proportionality coefficient;

$$c_{(\delta)} = \cos\left(\omega t_1 + \delta\right) - \cos\left(\omega t_2 + \delta\right) + f\left[\sin\left(\omega t_1 + \delta\right) - \sin\left(\omega t_2 + \delta\right)\right] - \frac{\cos\left(\alpha+\delta\right) + f\sin\left(\alpha+\delta\right)}{k}\left(\omega t_2 - \omega t_1\right) \quad (5)$$

$$H_{active\ part} > H \quad (6)$$

where $H_{active\ part}$ is the active part height of retaining elements;

$$H_{cascada.} \geq H_v \quad (7)$$

where $H_{cascade}$ is the first cascade's height;

H_v – matter's thickness;

$$H = \frac{\lambda q}{b\gamma_s v}; \quad (8)$$

where H_v is the vegetal matter's thickness;

λ – straw content coefficient out of total harvested mass;

q – combine feeding flow, kg/s;

b – threshing machine width, m;
γ_s – matter capacity mass, kg/m^3;

The matter capacity mass depends on the vegetal matter component and humidity at current combines due to straw pronounced fragmentation.
γ_s = 15…25 kg/m^3 [4] ;
v – displacement speed of matter on shaker, m/s;

$$\omega t_3 = \omega t_2 + A_{(\delta)} + \sqrt{A_{(\delta)}^{\ 2} + B_{(\delta)}}; \tag{9}$$

where ωt_3 is the angle of crank shaft at which the matter falls from the shaking element;

$$A_{(\delta)} = k\sqrt{1 + c_{(\delta)}^{\ 2} + 2c_{(\delta)}\cos\left(\omega t_2 + \delta\right)}\,\frac{\sin\left(\beta - \alpha\right)}{\cos\alpha};$$
$$B_{(\delta)} = \frac{c_{(\delta)} k\cos\delta}{\cos\alpha}\left(\omega t_2 - \omega t_1\right) - \frac{2k}{\cos\alpha}\left(\sin\omega t_3 - \sin\omega t_2\right); \tag{10}$$
$$\beta = \alpha + 90^0 - \omega t_2 + \arcsin\frac{c_{(\delta)}\sin\left(\omega t_2 + \delta\right)}{\sqrt{1 + c_{(\delta)}^{\ 2} + 2c_{(\delta)}\cos\left(\omega t_2 + \delta\right)}};$$

For calculating the size of jump over the sieve length S we use the relation:

$$S = \frac{r}{\cos\alpha}\left[\left(\omega t_3 - \omega t_2\right)\sqrt{1 + c_{(\delta)}^{\ 2} + 2c_{(\delta)}\cos\left(\omega t_2 + \delta\right)}\cos\beta + \cos\left(\omega t_3 - \alpha\right) - \cos\left(\omega t_2 - \alpha\right) - \frac{c_{(\delta)}}{2}\left(\omega t_2 - \omega t_1\right)\sin\left(\alpha + \delta\right)\right] \tag{11}$$

The matter displacement speed on shaker walkers disposed on two axes is calculated by the relation:

$$v = \frac{\omega r}{2\pi\cos\alpha}\left[\left(\omega t_3 - \omega t_2\right)\sqrt{1 + c_{(\delta)}^{\ 2} + 2c_{(\delta)}\cos\left(\omega t_2 + \delta\right)}\cos\beta + \cos\left(\omega t_3 - \alpha\right) - \cos\left(\omega t_2 - \alpha\right) - \frac{c_{(\delta)}}{2}\left(\omega t_2 - \omega t_1\right)\sin\left(\alpha + \delta\right)\right] \tag{12}$$

RESULTS AND DISCUSSION

The matter speed on the shaker determines the size of shaking losses and that’s why for reduced losses we must experimentally find out the optimum speed.

The increment of cascade and other active parts, of retaining elements tilting angle in comparison with sieves determines the diminishing of matter speed on shaker the increasing of matter jump numbers on shaking element, bigger values of displacement of matter H on cascades and active part of retaining elements and of vertical matter jump in comparison with sieves, the result being a better separation of seeds.

In figure 5 is shown the speed variation of matter on the shaker with walkers disposed on two axles depending on δ angle of cascades and retaining element part in comparison with sieve vertical and α angle reported to horizontal.

Following the analysis of two figures we can notice that:

- the value of matter speed varies inversely proportional with α and δ angles’ values;
- the value of matter speed diminishing δ>20^0;

for δ>20^0 values the differences of values of matter displacement on shaking element depending on shaker rotation speed is diminished, the optimum rotation speed being the smaller one.

In figure 6 is represented the speed variation of matter on shaker depending δ angle of cascades and retaining elements’ active part depending on sieve vertical and shaker rotation.

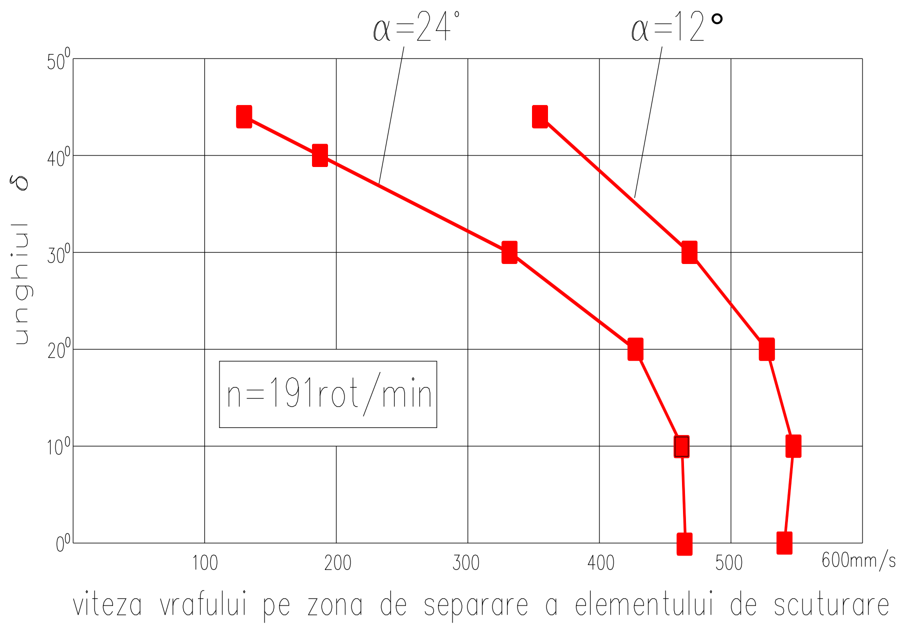

Figure 5. Matter speed on shaking element depending on α and δ angles

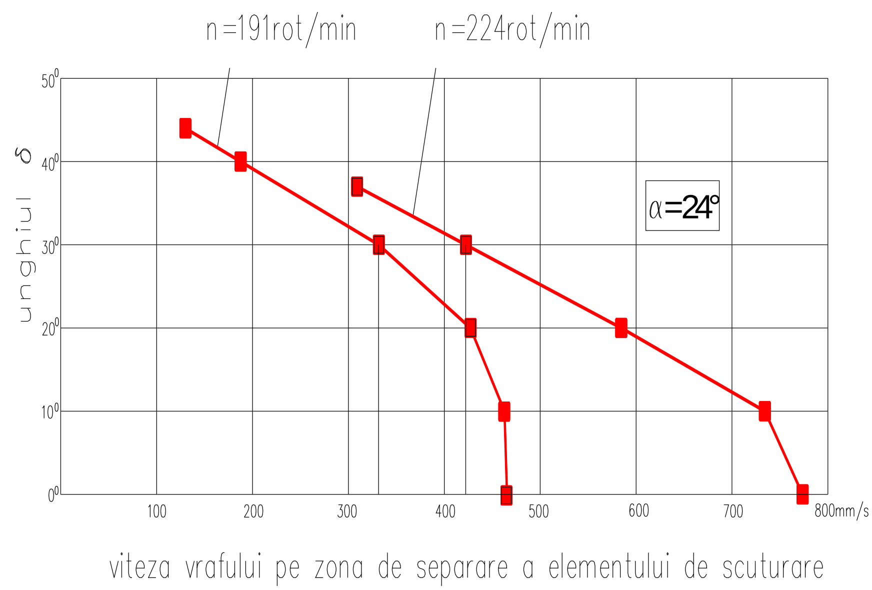

Figure 6. Matter speed on separating elements depending on δ angle and shaker rotation speed

CONCLUSIONS

1. The new theory regarding the vegetal matter displacement on shaker straw walkers disposed on two axes identifies and explains the importance of shaking elements' configuration which determines the matter displacement on this shaker.

2. This theory allows to calculate the shaker's constructive elements and functional characteristics, aiming at improving the shaking – separation processes for this shaker.

3. The theory emphasizes the importance of cascades, their angles and active part of retaining elements in comparison with shaking elements' sieves on the matter displacement characteristics and presents a calculation method of cascade height, retaining elements and sieve sill height.

4. For a shaker with walkers disposed on two axes at which on the separation area the cascade and active part of retaining elements are parallel and from $\delta > 20^0$ angle with sieves the vegetal matter moves as a whole with a steady speed whose value depends on α and δ angles.

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