# MATHEMATICAL MODELLING OF THE THRESHING PROCESS MADE BY THE THRESHING SYSTEMS WITH MULTIPLE ROTORS
/
# MODELAREA MATEMATICĂ A PROCESULUI DE TREIER REALIZAT DE APARATELE DE TREIER CU ROTOARE MULTIPLE

**Ph.D. Eng. Ivan Gh.**
[2)]INMA Bucharest/ Romania
*Tel: 0726190098; E-mail: geoivan2006@yahoo.com*

***Keywords:*** *combine harvester, tangential threshing system, threshing system with multiple rotors, threshing process, mathematical models*

## ABSTRACT
*The researches regarding the threshing process made by tangential threshing system of conventional harvester combines had as result the obtaining of mathematical models, based on experimental data, expressed through functions that partially define this process. Moreover, for the threshing systems with multiple rotors, the mathematical modelling of threshing process made by them is more difficult. This paper presents a mathematical model of the threshing process made by the threshing system with multiple rotors of the Romanian combine C110ATM. The mathematical model was based on the experimental data gathered by INMA Bucharest in 2001.*

## REZUMAT
*Cercetările privind procesul de treier realizat de aparatul de treier tangenţial al combinelor convenţionale de recoltat cereale au avut ca rezultat obţinerea de modele matematice pe baza datelor experimentale, exprimate prin funcţii care definesc doar parţial acest proces. Cu atât mai mult, pentru aparatele de treier cu rotoare multiple modelarea matematică a procesului de treier realizat de acestea este şi mai dificilă. Lucrarea de faţă prezintă un model matematic al procesului de treier realizat de aparatul de treier cu mai multe rotoare al combinei româneşti C110ATM. Modelul matematic prezentat s-a bazat pe datele experimentale realizate de INMA Bucureşti în anul 2001..*

## INTRODUCTION
The threshing process of the conventional combine harvesters is made by the tangential threshing system and consists in breaking the link between the seeds and plant and separating them through a concave. (*Scripnic V., Babiciu P., 1979*)

The tangential threshing system is the main work part of a conventional combine harvester in terms of seeds separation and is positioned in the technological flow of this combine between the feeder house and the straw walkers (*Segărceanu M., 1981*). (Fig.1)

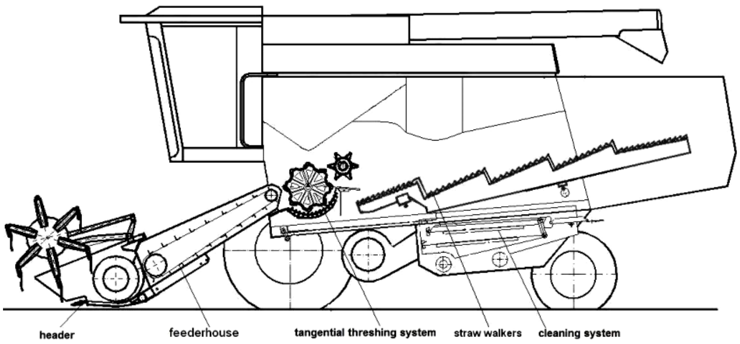



**Fig. 1 – Tangential threshing system in the technological flow of a conventional combine harvester**

In optimal conditions, the separation of seeds in tangential threshing system can be up to 85%, falling below 50-60% in the conditions of inadequate adjustments and a culture with high humidity. (*Miu P.1995*)

The tangential threshing system must ensure a threshing process with remained seeds in heads of grain under 1%, free seeds in straw under 14% and broken seeds under 2% of the harvested production. (*Segărceanu M., 1990*)

The main components of tangential threshing system are: threshing cylinder, concave, beater and concave extension (*Ivan Gh., Vlăduţ V., 2014*). (Fig. 2)

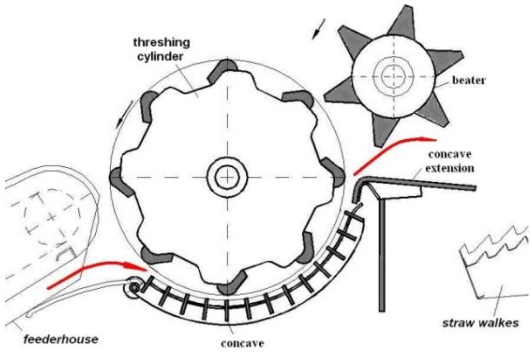
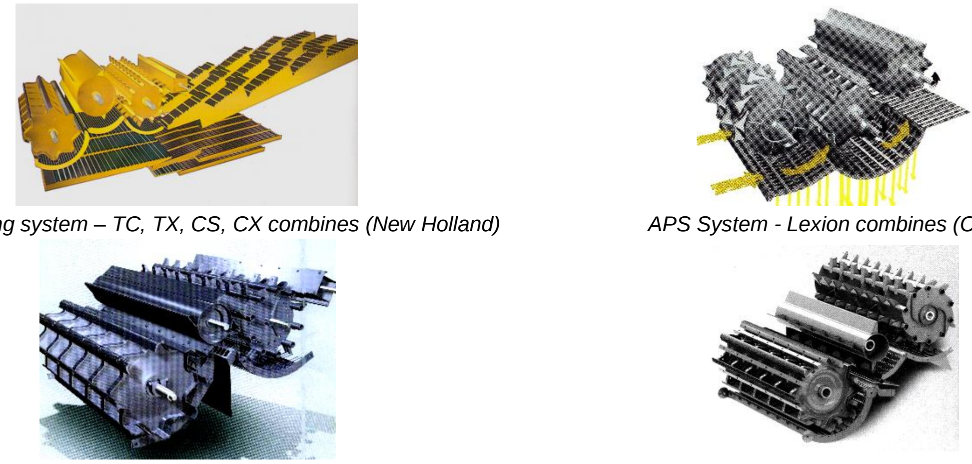



**Fig. 2 – Main components of the tangential threshing system**
(*Ivan Gh., Vlăduţ V., 2014*)

At the current combines equipped with tangential threshing system, in order to improve the threshing process, some firms use threshing systems with multiple rotors, that can be placed after the beater (*New Holland, Laverda*) or in front of the threshing cylinder (*Claas*), Fig. 3.



*Multi-threshing system – TC, TX, CS, CX combines (New Holland)* *APS System - Lexion combines (Claas)*

*Multi-threshing system with Optithresh concave - CS combines (New Holland)* *Multi Crop Separator - LXE, M300 combines (Laverda)*

**Fig. 3 – Threshing systems with multiple rotors**
(*Claas combine Prospects, Laverda combine Prospects, New Holland combine Prospects*)

At the threshing system with multiple rotors, the separation surface of seeds increases by 65-75%, the index of seeds separation being of 90-95%. (*Miu P.1995*)

The flow rate of a combine with threshing system with multiple rotors is higher by 14-20% than that of a conventional combine. (*Miu P.1995*)

Romanian combine C110ATM comprises a threshing system with multiple rotors, its location in the technological flow of the combine being shown in Fig. 4.

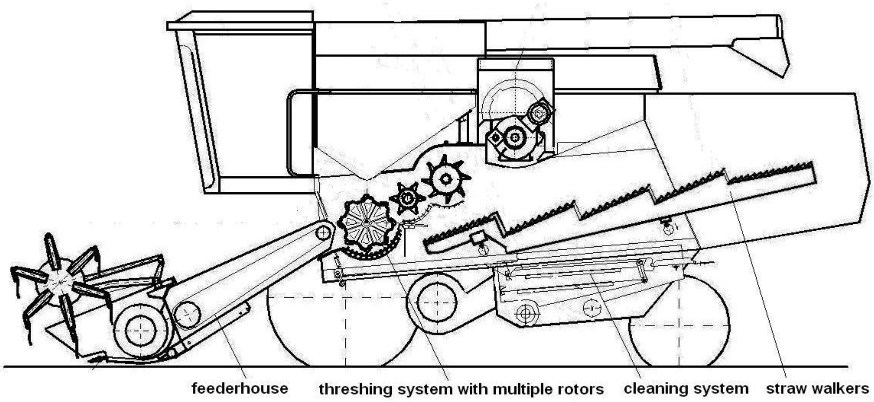



**Fig. 4 – Location of the threshing system with multiple rotors at C110ATM combine** (*Ivan Gh. ,2014*)

## MATERIAL AND METHOD

The threshing process takes place in the threshing space, positioned between threshing cylinder and concave, the characteristic dimensions of this being the concave radius $R_c$, the concave winding angle $\alpha$ and the distances $d_i$ and $d_e$ between threshing cylinder and concave. (Fig. 5)

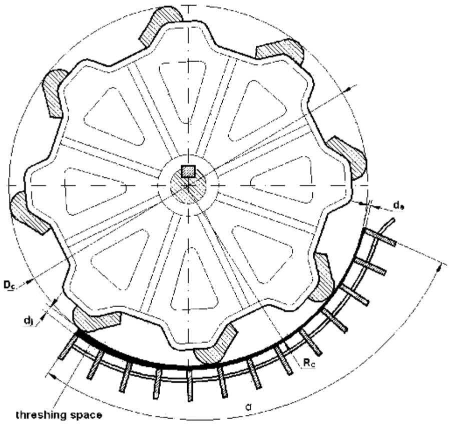



**Fig. 5 – Threshing space of the tangential threshing system** (*Ivan Gh., 2014*)

The threshing space length of the tangential threshing system can be calculated with relationship 1. (*Miu P.1995*)

$$s = \pi R_c \frac{\alpha}{180^0} \quad [\text{m}] \tag{1}$$

wheres is length of the threshing space; $R_c$– radius of the concave; $\alpha$ - winding angle of the concave.

The researches regarding the threshing process in the tangential threshing system had as a result the obtaining of mathematical models based on experimental data, expressed by functions that partially define the threshing process, the method used being the linear mathematical regression, nonlinear or multiple. (*Miu P., 1995*)

We present below the most important mathematical models concerning the percentage of seeds separated by concave depending on the length of threshing space at the conventional combines. (*Maertens K., De Baerdemaeker J. 2003, Rusanov A.I., 1974*)

**Table 1**

**Mathematical models of the threshing process at the conventional combines**

(*Maertens K., De Baerdemaeker J. 2003, Rusanov A.I., 1974*)

| Model | Structure | Notations |
|---|---|---|
| **Casper (1973)** | $\xi_s(s) = 100\left(1 - e^{-\left(k_1 s + k_2 s^2 + k_3 s^3\right)}\right)\%$ | where $\xi_s(s)$is the percentage of seeds separated by concave depending on the length of threshing space; $s$ – length of the threshing space, in m; $k_1$, $k_2$, $k_3$ –threshing coefficients (experimental). |
| **Rusanov A.J. (1976)** | $\xi_s(s) = 100\left(1 - e^{-\mu s^{\alpha}}\right)\%$ | $\alpha$ – winding angle of the concave, in radians; $\mu$ –threshing coefficient (experimental). |
| **Trollope J.R. (1982)** | $\xi_s(s) = 100\left[1 + \frac{ce^{-kP_0\psi} - kP_0 e^{-c\psi}}{kP_0 - c}\right]\%$ | $k$, $c$ – experimental coefficients; $\Psi$ –geometric function on the winding angle. |
| **Miu Petre (1995)** | $\xi_s(s) = \frac{100}{a - b}\left[a\left(1 - e^{-bs}\right) - b\left(1 - e^{-as}\right)\right]\%$ | $s$ – length of the threshing space, in m; $a$, $b$ – threshing coefficients (experimental). |
| **Klenin N.I. and Lomakin S.G. (1972)** | $\frac{d\xi_s(s)}{ds} = 100\left[1 - \frac{A}{k_2\mu}\left(k_2 e^{\mu s} - e^{k_2 s}\right) - \left(1 - A\right)e^{\mu s}\right]\%$ | $s$ – length of the threshing space , in m; $A$, $k_2$, $\mu$ –threshing coefficients (experimental). |
| **Alferov S.A and Braginec V.S. (1972)** | $\xi_s(s) = 100\left[1 - e^{-k_1 s} - A\frac{e^{-k_0 s} - e^{-k_1 s}}{k_1 - k_0}\right]\%$ | $s$ – length of the threshing space , in m; $A$, $k_0$, $k_1$–threshing coefficients (experimental). |

Koen Maertens and Josse De Baerdemaeker have published in 2003 the results of experiments performed at stationary on the tangential threshing system of a New Holland combine harvester for feeding rates of 25-45 t/h (6.94-12.5 kg/s) 15.5-15.9% seeds humidity, 12-13% straw humidity, comparing with the 6 mathematical models shown in Table 1, the best results being achieved by mathematical models Rusanov, Caspers and Alferov-Braginec, in that order. (*Maertens K., De Baerdemaeker J. 2003*)

C110 combine harvester of the Romanian company "SEMĂNĂTOAREA", started to be manufactured in 1994. After year 2000, researches were made at INMA Bucharest, to increase the working capacity of this combine, by introducing a threshing system with multiple rotors (ATM), yielding an increase of the seeds separation surface at the level of threshing system with 84%.(*Prototype tests report for ATM, INMA Bucharest, 2002*)

The constructive scheme of the threshing system with multiple rotors at C110ATM combine is presented in Figure 5. (*Ivan Gh., 2014*)

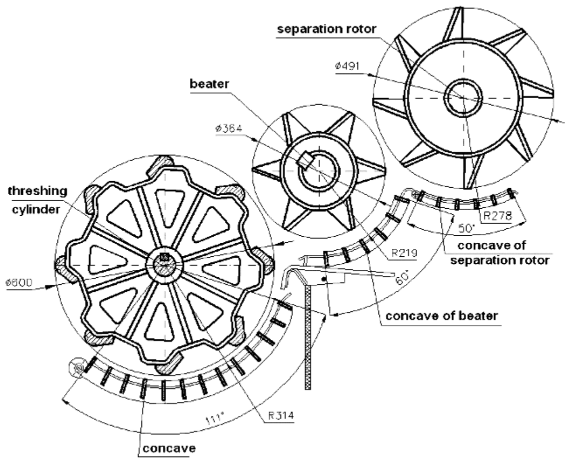



**Fig. 6 - Constructive scheme of the threshing system with multiple rotors at C110ATM combine**
*(Ivan Gh., 2014*)

Characteristic for ATM is possibility to rotate the last two concaves (hereinafter called separation concaves), their threshing function canceling, the rotor separation just having the role of transporting and directing the straw. The canceling of this function is made if the harvesting exceeds the optimum period, because in this case there is an excessive straw shredded with negative effects on shaking and cleaning processes. (*Prototype tests report for ATM, INMA Bucharest, 2002*)

Technical features of the threshing system with multiple rotors at C110ATM combine harvester are presented in Table 2. (*Prototype tests report for ATM, INMA Bucharest, 2002*)

**Table 2**

**Technical features of the threshing system with multiple rotors at C110ATM combine harvester**

| | | |
|---|---|---|
| **Threshing cylinder** | diameter [mm] | 600 |
| | length [mm] | 1080 |
| | number of bars | 8 |
| | RPM [rot/min] | 460-1200 |
| **Concave** | number of bars | 13 |
| | surface [ $m^2$] | 0.67 |
| | winding angle | 111° |
| **Beater** | diameter [mm] | 360 |
| | RPM [rot/min] | 760 |
| **Separation rotor** | diameter [mm] | 491 |
| | RPM [rot/min] | 920 |
| **Beater concave** | number of bars | 7 |
| | winding angle | 60° |
| | surface [$m^2$] | 0.303 |
| | fixed distance between beater and concave [mm] | 25 |
| **Separation rotor concave** | number of bars | 6 |
| | winding angle | 50° |
| | surface [$m^2$] | 0.253 |
| | fixed distance between rotor and concave [mm] | 25 |

The mathematical model of the threshing process made by the threshing system with multiple rotors ATM, which we propose, is based on the mathematical model of Rusanov, considered by researchers Koen Maertens and Josse De Baerdemaeker as the mathematical model which best describes the separation seeds in the tangential threshing system. *(Ivan Gh., 2014)*

Thus, the percentage of seeds separated by the concaves ATM, depending on the length of threshing spaces and the winding angles size of the concaves, is given by relationship 2. (*Ivan Gh. ,2014*)

$$\xi_{sATM}(s) = 100\left[1\text{-}e^{-\left(\mu_1 s_1^{\alpha_1}+\mu_2 s_2^{\alpha_2}+\mu_3 s_3^{\alpha_3}\right)}\right] \quad [\%] \qquad (2)$$

where $\xi_{sATM}(s)$ is the percentage of seeds separation in ATM; $s_1$ – the threshing space length of the concave; $s_2$ – the threshing space length of the beater concave; $s_3$ – the threshing space length of the separation rotor concave; $\alpha_1$ – thewinding angle of the concave; $\alpha_2$– the winding angle of the beater concave; $\alpha_3$– the winding angle of the separation rotor concave; $\mu_1$ – the threshing coefficient for seeds separation through concave; $\mu_2$ – the threshing coefficient for seeds separation through beater concave; $\mu_3$ – the threshing coefficient for seeds separation through separation rotor concave.

The threshing space length of ATM concave is calculated with the relationship 3.

$$s_1 = \pi R_{c1}\frac{\alpha_1}{180^0} \quad [\text{m}] \qquad (3)$$

where$s_1$is the threshing space length of ATM concave; $R_{c1}$– radius of the concave; $\alpha_1$**–** thewinding angle of the concave.

The threshing space length of beater concave is calculated with the relationship 4. (*Ivan Gh., 2014*)

$$s_2 = \pi R_{c2}\frac{\alpha_2}{180^0} \quad [\text{m}] \qquad (4)$$

where$s_2$is the threshing space length of beater concave; $R_{c2}$– radius of the beater concave; $\alpha_2$**–** thewinding angle of the beater concave.

The threshing space length of separation rotor concave is calculated with the relationship 5. (*Ivan Gh., 2014*)

$$s_3 = \pi R_{c3}\frac{\alpha_3}{180^0} \quad [\text{m}] \qquad (5)$$

where$s_3$is the threshing space length of the separation rotor concave; $R_{c3}$– radius of the separation rotor concave; $\alpha_3$**–** thewinding angle of separation rotor concave.

The sum consists of the percentage of free seeds remaining in straw and the percentage of seeds no threshing of the bale coming from the threshing cylinder of ATM (the separation concaves are out of the threshing flow) is given by relationship 6. (*Ivan Gh., 2014*)

$$\xi_l(s)+\xi_n(s) = 100e^{-\mu_1 s_1^{\alpha_1}} \quad [\%] \qquad (6)$$

where $\xi_l(s)$ is the percentage of free seeds remaining in straw found at the exit from the threshing space located between threshing cylinder and concave; $\xi_n(s)$- the percentage of seeds non threshed at the exit from the threshing space located between threshing cylinder and concave; $\mu_1$ - the threshing coefficient for seeds separation through concave; $s_1$ - the threshing space length of the concave; $\alpha_1$- thewinding angle of concave.

The sum consists of the percentage of free seeds remaining in straw and the percentage of seeds non- threshed of the bale coming from all rotors of ATM is given by the relationship 6. (*Ivan Gh., 2014*)

$$\xi_{lATM}(s)+\xi_{nATM}(s) = 100e^{-\left(\mu_1 s_1^{\alpha_1}+\mu_2 s_2^{\alpha_2}+\mu_3 s_3^{\alpha_3}\right)} \quad [\%] \qquad (7)$$

where $\xi_{lATM}(s)$is the percentage of free seeds remaining in straw found at the exit from ATM; $\xi_{nATM}(s)$- the percentage of non- threshed seeds at the exit from ATM; $\mu_1$ - the threshing coefficient for seeds separation through concave; $\mu_2$ - the threshing coefficient for seeds separation through beater concave; $\mu_3$ - the threshing coefficient for seeds separation through separation rotor concave; $s_1$ - the threshing space length of concave; $s_2$ - the threshing space length of beater concave; $s_3$ - the threshing space length of separation rotor concave; $\alpha_1$- thewinding angle of concave; $\alpha_2$- thewinding angle of beater concave; $\alpha_3$- thewinding angle of separation rotor concave.

The relations 6 and 7 represent the losses related to threshing processes made by ATM, to which the separation concaves were taken out of the flow of material (similarly the threshing system of conventional combine C110) and ATM at which the separation concaves were introduce in the threshing flow.

The report of the relations 7 and 6 represents the loss report of the two types of the threshing systems (of the combines C110ATM and C110), according to the relationship 8. *(Ivan Gh., 2014)*

$$\frac{\xi_{lATM}(s)+\xi_{nATM}(s)}{\xi_l(s)+\xi_n(s)}=e^{-\left(\mu_2 s_2^{\alpha_2}+\mu_3 s_3^{\alpha_3}\right)} \quad (8)$$

The losses report of the two types of threshing systems equals with the report of total losses to straw walkers of combine C110ATM.

The separation concaves, having the same configuration, $\mu_1$ and $\mu_2$ threshing coefficients can be considered equal and having $\mu_{ATM}$ value, resulting in the relationship 9. (*Ivan Gh., 2014*)

$$\frac{\xi_{lATM}(s)+\xi_{nATM}(s)}{\xi_l(s)+\xi_n(s)}=e^{-\mu_{ATM}\left(s_2^{\alpha_2}+s_3^{\alpha_3}\right)}=k \quad (9)$$

Where $\mu_{ATM}$ is the threshing coefficient of the separation concaves of ATM; $k$ – the losses report value of the two types of threshing systems.

Knowing the losses report value of the two threshing systems types, it results the threshing coefficient value μATM of the separation concaves of ATM, according to the relationship 10. (*Ivan Gh., 2014*)

$$\mu_{ATM}=-\frac{\ln k}{s_2^{\alpha_2}+s_3^{\alpha}} \quad (10)$$

where $\mu_{ATM}$is the threshing coefficient of the separation concaves of ATM; $k$ – the losses report value of the two types of threshing systems; $s_2$ - the threshing space length of beater concave; $s_3$ - the threshing space length of separation rotor concave; $\alpha_2$- thewinding angle of beater concave; $\alpha_3$- thewinding angle of separation rotor concave.

The intensification value of the threshing process made by the ATM threshing system with multiple rotors reported to the threshing process made by the threshing system of the conventional combine C110, is given by relationship 11. *(Ivan Gh., 2014)*

$$I_{ATM}=100\frac{\xi_l(s)+\xi_n(s)}{\xi_{lATM}(s)+\xi_{nATM}(s)}\ [\%] \quad (11)$$

where $I_{ATM}$ is intensification of threshing process made by the threshing system with multiple rotors ATM, reported to the threshing process of the conventional combine C110; $\xi_l(s)$- the percentage of free seeds remaining in straw at the exit from the threshing system of C110 combine; $\xi_n(s)$- the percentage of non-threshed seeds at the exit from the threshing system of C110 combine; $\xi_{lATM}(s)$- the percentage of free seeds remaining in straw at the exit from ATM; $\xi_{nATM}(s)$- the percentage of non-threshed seeds at the exit from ATM.

## RESULTS

The laboratory tests of the C110ATM combine harvester were conducted in June 2001 by DITRMA-INMA Bucharest Laboratory and field tests were conducted in July 2001 in Dor Mărunt locality, Calăraşi County. (*Prototype tests report for ATM, INMA Bucharest, 2002*)

In Table 3 are presented the values of the working regime and working quality indices for the tests with the separation concaves of ATM introduced into the material flow. (*Prototype tests report for ATM, INMA Bucharest, 2002*).

**Table 3**

**The working regime and working quality indices for the tests with the separation concaves of ATM introduced into the vegetal mass flow**

| No. | Index | M.U. | Value determined | |
|---|---|---|---|---|
| **WORKING REGIME** | | | | |
| 1 | Working speed | km/h | 3,789 | 6,426 |
| 2 | Flow rate combine | kg/s | **4,299** | **6,027** |
| 3 | Working width | m | 4,1 | |
| 4 | Cutting height | m | 0,16 | 0,17 |

| No. | Index | M.U. | Value determined | |
|---|---|---|---|---|
| WORKING QUALITY INDEXES | | | | |
| 1 | Total losses per hectare at header:<br>- seeds in uncut ears<br>- seeds in cut ears<br>- free seeds on the ground | % | 0,2958<br>0,1472<br>0,1205<br>0,0281 | 0,3735<br>0,1872<br>0,1426<br>0,0437 |
| 2 | Total losses at threshing machine:<br>- total losses at straw walkers<br>- seeds in non-threshed ears<br>- free seeds in straw<br>- total losses at cleaning system | % | 1,2314<br>**0,0785**<br>0,0032<br>0,0753<br>1,1529 | 1,3124<br>**0,0839**<br>0,0027<br>0,0812<br>1,2285 |
| 3 | Total losses at combine | % | 1,5272 | 1,6859 |
| 4 | Broken seeds | % | 1,64 | 1,78 |
| 5 | The purity of the material collected in bunker | % | 99,59 | 99,41 |

In Table 3 are presented the values of the working regime and working quality indices for the tests with the separation concaves of ATM removed from the material flow. (*Prototype tests report for ATM, INMA Bucharest, 2002*).

**Table 4**

**The working regime and working quality indices for the tests with the separation concaves of ATM removed from the material flow**

| No. | Index | M.U. | Value determined | |
|---|---|---|---|---|
| WORKING REGIME | | | | |
| 1 | Working speed | km/h | 3.747 | 6.286 |
| 2 | Flow rate combine | kg/s | **4.186** | **5.988** |
| 3 | Working width | m | 4.1 | |
| 4 | Cutting height | m | 0.15 | 0.19 |
| WORKING QUALITY INDEXES | | | | |
| 1 | Total losses per hectare at header:<br>- seeds in uncut ears<br>- seeds in cut ears<br>- free seeds on the ground | % | 0.3167<br>0.1272<br>0.1523<br>0.0372 | 0.3683<br>0.1659<br>0.1626<br>0.0398 |
| 2 | Total losses at threshing machine:<br>- total losses at straw walkers<br>- seeds in no threshing ears<br>- free seeds in straw<br>- total losses at cleaning system | % | 1.7594<br>**0.3501**<br>0.0663<br>0.2838<br>1.4093 | 2.0556<br>**0.4292**<br>0.0807<br>0.3485<br>1.6264 |
| 3 | Total losses at combine | % | 2.0761 | 2.4239 |
| 4 | Broken seeds | % | 1.69 | 1.73 |
| 5 | The purity of the material collected in bunker | % | 99.72 | 99.45 |

By entering the relationship 10 the test report data for the combine C110ATM for the total loss obtained at the straw walkers for the two positions of the separation concaves (similar to the two threshing system of C110 and C110ATM combines). the threshing coefficient values $\mu_{ATM}$ of the separation concaves and the intensification of threshing process $I_{ATM}$ of ATM. are calculated according to Table 5.

**Table 5**

**The threshing coefficient values of the separation concaves and the intensification of threshing process of ATM**

(*Ivan Gh. .2014.Test results for approval of C110 self-propelled combine harvester cereal. INMA Bucharest. 1990*)

| No. | Index | M.U. | Value determined | | | |
|---|---|---|---|---|---|---|
| | | | **C110** | **C110ATM** | **C110** | **C110ATM** |
| **WORKING REGIM** | | | | | | |
| 1 | Flow rate of combine | kg/s | 4.2* | | 6.0* | |
| 2 | Total losses at straw walkers | % | 0.3501 | 0.0785 | 0.4292 | 0.0839 |
| **WORKING QUALITY INDICES** | | | | | | |
| 1 | Threshing coefficient $\mu_{ATM}$ | - | 2.963 | | 3.235 | |
| 2 | Intensification of threshing process $I_{ATM}$ | % | 51.15 | | 44.60 | |

* The flow rate combines have been rounded to the first decimal

Analyzing the values presented in Table 5 it has resulted:

- The threshing coefficient. specific to ATM. has a variable value. increasing along with the flow rate value;

- ATM intensifies considerably the threshing process. the intensification value being variable. and decreasing according to the flow rate value;
- The small values of total losses of C110ATM combine harvester. it would require to test the combine at bigger flow rates .

## CONCLUSIONS

1. The threshing systems with multiple rotors have the separation surface bigger by 65-75%. related to the separating surface of the tangential threshing system. which would allow the decreasing of straw walkers length;
2. The threshing systems with multiple rotors produces an intensification of the threshing process related to the tangential threshing system. but this does not mean that the flow rate must increase with equal percentage value. This explains why the flow rate of a combine with threshing system with multiple rotors is bigger only by 14-20% referring to the flow rate of a conventional combine harvester. (*Miu P.1995*)
3. The increase of threshing space length at the threshing system with multiple rotors has led to shredding the straw. being necessary changes of the straw walkers and the cleaning system. It also increases the specific energy consumption;
4. Combines with threshing system with multiple rotors are less universal. these being effective only for certain crops. the crops with large seeds (maize) or the crops with seeds more sensitive when harvesting with cereal combine harvester (sunflower. soybeans. beans . peas etc.). which can not be harvested with these combines;
5. The combines with threshing systems with multiple rotors are more complex. more expensive. harder to maintain and more susceptible to clog in case of crops with weeds and with high humidity;
6. The combines with threshing systems with multiple rotors are recommended for the cereals harvesting provided that the investment and modifications to the conventional combines be relatively low.

## REFERENCES

[1] Ivan Gh. (2014), The threshing systems of combines harvester cereals. Terra Nostra Publisher. Iaşi;
[2] Ivan Gh.. Vlăduț V., (2014), Kinematic study of threshing process conducted by the tangential threshing system of conventional combine of cereal harvesting. *ISB-INMATEH 2014 Proceedings - International Symposium*; pp.65-74, Bucharest/Romania;
[3] Ivan Gh., Vlăduț V., (2015), Improving threshing system feeding with vegetal mass to conventional combine of cereal harvesting. *International Symposium XLIII,* pp.431,-440, Opatija/Croatia;
[4] Maertens K., De Baerdemaeker J., (2003), Flow rate based on prediction of threshing process in combine harvesters. *American Society of Agricultural Engineers,* Volume 19, pp.383–388, USA;
[5] Miu P., (1995), Modellingof the threshing process in cereal combine harvesters. *PhD.thesis,* University Politehnica of Bucharest;
[6] Rusanov A.I., (1974), Constructia triernih priborov razlicinih diametrov (Construction of the threshing systems with various diameters), *Magazine mechanization and electrification of agriculture,* No.6, Moscow/Rusia;
[7] Scripnic V., Babiciu P., (1979), Agricultural machines. Ceres Publisher House, pp.296-304 Bucharest/Romania;
[8] Segărceanu M., (1981), *Studies and researches on improving the quality parameters and computer modelling of the work process of the threshing system at combine harvesters cereal*, Polytechnic Institute of Bucharest;
[9] Segărceanu M., (1990), Calculation and construction of the agricultural machinery for harvesting. *Course* Polytechnic University of Bucharest;
[10] *** (1990), Test results for approval of C110 self-propelled combine harvester cereal, INMA Bucharest, Romania;
[11] *** (2002), Prototype tests report for ATM, INMA Bucharest, Romania;
[12] *** (1980…2008), CLAAS combine Prospectuses;
[13] *** (1980…2008), LAVERDA combine Prospectuses;
[14] *** (1980…2008), NEW HOLLAND combine Prospectuses.