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CONTRIBUTIONS TO MODELLING THE THRESHING AND SEPARATING PROCESS WITHIN A THRESHING APPARATUS WITH AXIAL FLOW

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În lucrare s-a urmărit realizarea unui model matematic care caracterizează procesul de treier şi separare dintr-un aparat de treier cu flux axial (batoză B 90), luându-se în consideraţie 7 din cei mai importanţi parametri de intrare: Q (kg/s), n (rot/min), δ (m), ρ (kg/m^3), v_a (m/s), L (m) şi S (m^2). Pentru a controla procesul de modelare au fost stabiliţi şi parametrii de ieşire, respectiv: S_s - funcţia de repartiţie a seminţelor separate, S_d - funcţia densitate de repartiţie a seminţelor separate, S_l - funcţia de repartiţie a seminţelor libere în spaţiul de treier şi S_n - funcţia de repartiţie a seminţelor netreierate, p_{ev} - valoarea pierderilor la evacuare.

The aim of this paper was to obtain a mathematical model for characterizing the threshing and separating process within the axial flow of the threshing apparatus (B90 thresher), taking into consideration only 7 of the most important input parameters: Q (kg/s), n (rpm), δ (m), ρ (kg/ m^3), v_a (m/s), L (m) and S (m^2). In order to control the modelling process there were also established the output parameters: S_s - the probability distribution of separated seeds, S_d - the density function of the separated seeds, S_l - the probability distribution of free seeds within the threshing area and S_n - the probability distribution of unthreshed seeds, p_{ev} - value of exhaust losses.

Keywords: modelling, threshing apparatus, seeds, separation

1. Introduction

The performing of the working process of a threshing apparatus is strongly influenced by the physical - mechanical properties of the processed material, which depend on the crop type and sort, on the pedo-climatic conditions of growing and developing and on the harvesting conditions.

The plant cutting height varies nearly continuously during the work as long as the harvester follows the ground unevenness. Consequently for the

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harvested material the ratio $i = SS/PP$ (seeds/straw) or the values of the straw content μ or of the seed content τ, mostly used in the calculations regarding the harvester working capacity, should vary between certain limits.

$i = \frac{SS}{P}$; It results $\mu = \frac{P}{SS + P}$ and $\tau = \frac{SS}{SS + P}$;

For a certain quantity of material the variation of this feature, devided by the effective threshing time, is negligible [4], within the assumptions:

the ratio SS/PP is considered to be constant;

the material is considered approximately homogenous when feeding the threshing apparatus, respectively the ears are uniformly distributed into the straw parts mass and the material density is approximately the same along the whole width of the feeding surface;

the vegetal material is introduced into the threshing apparatus and it moves inside it under the form of a continuous stratum;

the material sliding resistance within the threshing area is a combination between the dynamic friction and the mechanical interaction;

the free seeds move within the area between the rotor and the carcass until they are separated with the same speed as the mixture of the straw part and the unthreshed ears;

in the threshing area the material is homogenous in a given radial section;

the material mass is continuously distributed in the threshing area;

the density of a material volume element continuously varies from the input to the threshing apparatus to the output, due to:

the threshed seeds separation;

the straw compression and crushing;

the variation of the material speed (the feeding material flow rate is considered to be constant).

2. Applying the theory of similitude of modelling for threshing process

For modelling the threshing process the following physical parameters are established as input parameters process for the:

Q – material flow rate of the threshing apparatus[kg/s];

n – rotor rotative speed [rpm];

δ – distance between rotor and counter - rotor [m];

ρ – bulk density of the processed material [kg/cu.m];

v_a – feeding speed [mps];

L – length of threshing apparatus [m];

$i = \frac{SS}{PP}$ - seed/straw ratio;

S – the area of feeding section;

D - rotor diameter of threshing apparatus [m].

Among some of these parameters it is considered, through an acceptable hypothesis from a physical point of view, the relation:

$$Q = \rho \cdot S \cdot v_a, \tag{2.1}$$

The material could be assimilated as being a "fluid" comprising the following stages: seeds, chaff, impurities, dust, air and possibly soil particles. The mean density of this heterogeneous "fluid" is denoted by ρ. In this context if the size S of the material admission area is an adjustable parameter or variable from one apparatus to another, it is advisable to include it into the parameter list, while for fixed values, it may be eliminated from the list of variables. For the sake of generalization, this parameter will be rather maintained along the following calculations.

The "output" parameters of the process are:

S_d - density function of separated seeds in threshing apparatus;

S_s - separated seeds in threshing apparatus;

S_v - damaged seeds in threshing apparatus;

p_{ev} - losses when exhausting.

According to Miu's hypothesis [4] based on Lipkovich's model [3], the following formula is accepted for the density function of the separated seeds:

$$S_d(x) = \frac{\lambda \cdot \beta}{\lambda - \beta} \cdot \left(e^{-\beta x} - e^{-\lambda x}\right). \tag{2.2}$$

For the probability distribution of the separated seeds the expression obtained by integrating the relation (2.2), is accepted whose primitive is under the form:

$$S_s(x) = \int_0^x S_d(u)\,du = \frac{1}{\lambda - \beta} \cdot \left(\beta \cdot e^{-\lambda x} - \lambda \cdot e^{-\beta x}\right) + 1, \tag{2.3}$$

But in order that (2.3) relation be the probability distribution function of the expression (2.3) relatively to the working interval [0, L], where L is the length of the distribution interval of the threshed material, the following conditions should be fulfilled:

$$S_s(0) = 0, \tag{2.4}$$

and

$$S_s(L) = 1. \tag{2.5}$$

The condition (2.4) is fulfilled by the definition (2.3) of the probability distribution of separated seeds and the conditions (2.5) leads to the following connection between the parameters λ and β:

$$\lambda = \beta + \frac{1}{L} \cdot \ln\frac{\beta}{\lambda} \tag{2.6}$$

Consequently, the two parameters of the density function of the separated seeds, λ and β, are not independent, but rather connected through the relation (2.6), which should be used in the computation of the coefficients of unknown functions based on experimental data. In order to deliver a physical meaning, the parameters must possess the dimension L^{-1}. The physical dimensions of all the parameters involved into the process are given in table 1.

Table 1

Physical Dimensions of the Parameters Involved into the Process

Den. No.	Parameter	Exponent L (length)	Exponent M (mass)	Exponent T (time)
1.	λ	-1	0	0
2.	n	0	0	-1
3.	δ	1	0	0
4.	v_a	1	0	-1
5.	ρ	-3	1	0
6.	L_t	1	0	0
7.	Q	0	1	-1
8.	S_s	0	1	0
9.	p_{ev}	0	1	0

Thus: $\lambda = [L^{-1}]$; $n = [T^{-1}]$; $\delta = [L]$; $v_a = [LT^{-1}]$; $\rho = [ML^{-3}]$; $L_t = [L]$ and $Q = [MT^{-1}]$

The relation behaves among the functions S_s, S_l and S_n:

$$S_s(x) + S_l(x) + S_n(x) = 1, \tag{2.7}$$

The losses are given by the formulas:

$$p_{tr} = \int_0^L S_n(x)dx,\ p_{sr} = \int_0^L S_l(x)dx,\ p_{ev} = \int_0^L (1 - S_s(x))dx, \tag{2.8}$$

where: S_l - free seed in straw layer; S_n - non separation seed in straw layer; p_{tr} - loses in threshing process; p_{sr} - loses in separation process;

Between the probability distribution S_s and the density function, S_d, the relation subsists:

$$\frac{dS_s(x)}{dx} = S_d(x). \tag{2.9}$$

This can also be written under the form:

$$\frac{dS_s(x)}{dx} = \beta S_l(x)\ [4] \qquad (2.10)^{6)}$$

where: β - separation coefficient $[L^{-1}]$;

The size of the considered dimensional space is $r = 3$, and the number of considered independent parameters is $N = 7$, namely: λ, n, δ, Q, v_a, ρ, L derives from Table 1. Among the seven parameters enumerated above the relation (2.1) connecting three of them exists. Consequently, one of these parameters can be eliminated from the calculation. On the other hand, it is absolutely necessary to take at least one of the parameters, Q or ρ, among the basic physical as otherwise the massic reference is lost. Even if one works with the complete set of

6) (2.10) is a hypothesis belonging to the author Miu, which we for the time being adopt, but in the subsequent form of the researches it will be put under discussion!

parameters and the relation (2.1) is not used, its removal can be also performed after concluding the dimensional analysis. According to the theorem *Π* of the dimensional analysis, the phenomen is characterized by a number of "$N - r = 4$" non-dimensional combinations and a function, *F*, connecting them according to the relation:

$$\Pi_5 = F(\Pi_1, \Pi_2, \Pi_3, \Pi_4) \tag{2.11}$$

From the set of parameters describing the phenomenon, We have chosen three parameters as fundamental (whose dimensional determinant should be different from zero). The three fundamental parameters are chosen by tests, as: n, δ and Q. The fundamental determinant is governing them (on the basis of their coefficients).

$$\begin{bmatrix} 0 & 0 & -1 \\ 1 & 0 & 0 \\ 0 & 1 & -1 \end{bmatrix} = -1 \neq 0 \cdot$$

Taking into consideration that the fundamental determinant is non-zero, it results that among them an interdependence relation exists and going on, a non-dimensional combination for each of the "$N\text{-}3 = 4$", remained parameters: λ, v_a, ρ, L_t and $S = Q/v_a \cdot \rho$ will be established, depending on the three previously selected fundamental parameters.

Thus it results:

$$\begin{cases} \Pi_5 = \dfrac{\lambda}{n^{x_5} \delta^{y_5} Q^{z_5}} \\ \Pi_1 = \dfrac{v_a}{n^{x_1} \delta^{y_1} Q^{z_1}} \\ \Pi_2 = \dfrac{\rho}{n^{x_2} \delta^{y_2} Q^{z_2}} \\ \Pi_3 = \dfrac{L_t}{n^{x_3} \delta^{y_3} Q^{z_3}} \\ \Pi_4 = \dfrac{\dfrac{Q}{\rho v_a}}{n^{x_4} \delta^{y_4} Q^{z_4}} \end{cases} \tag{2.12}$$

are the non-dimensional looked for combinations (products).

Each of the non-dimensional products, interdependent among each other, is written in the non-dimensional form: $\lambda = [L^{-1}]$; $n = [T^{-1}]$; $\delta = [L]$; $v_a = [LT^{-1}]$; $\rho = [ML^{-3}]$; $L_t = [L]$ and $Q = [MT^{-1}]$. The suitable dimensional equations result:

$$\Pi_5 = \frac{\lambda}{n^{x_5}\delta^{y_5}Q^{z_5}} = \frac{L^{-1}}{T^{-x_5}\cdot L^{y_5}\cdot M^{z_5}T^{-z_5}} \quad \Rightarrow L^{y_5}M^{z_5}T^{x_5 z_5} = L^{-1}\cdot M^{0}\cdot T^{0} \Rightarrow$$

$$\Pi_5 = \frac{\lambda}{\delta^{1}} = \lambda\delta$$

As far as $\Pi_5 = F(\Pi_1,\Pi_2,\Pi_3,\Pi_4)$ and $\Pi_5 = \lambda\cdot\delta \Rightarrow$ $\lambda = \frac{1}{\delta}F(\Pi_1,\Pi_2,\Pi_3,\Pi_4)$.

Similarly, the product $\Pi_1 = \frac{v_a}{n^{x_1}\delta^{y_1}Q^{z_1}} \Rightarrow \Pi_1 = \frac{v_a}{n^{x_1}\delta^{y_1}Q^{z_1}} = \frac{v_a}{n\delta}$.

For the product $\Pi_2 = \frac{\rho}{n^{x_2}\delta^{y_2}Q^{z_2}} \Rightarrow \Pi_2 = \frac{\rho}{n^{x_2}\delta^{y_2}Q^{z_2}} = \frac{\rho}{n^{1}\delta^{3}Q} = \frac{\rho n\delta^{3}}{Q}$.

By proceeding in a similar way, the other non-dimensional products: Π_3 and Π_4, result:

$$\begin{cases} \Pi_5 = \lambda\cdot\beta \\ \Pi_1 = \dfrac{\rho n\delta^{3}}{Q} \\ \Pi_2 = \dfrac{v_a}{n\delta} \\ \Pi_3 = \dfrac{L_t}{\delta} \\ \Pi_4 = \dfrac{\dfrac{Q}{\rho v_a}}{\delta^{2}} \end{cases} \tag{2.13}$$

from which the unknown exponents x_i, y_i, z_i will also result, where: i = 1, 2, 3, 4, 5. The final form of dependence (2.11) results:

$$\lambda = \frac{1}{\delta}F\left(\frac{\rho n\delta^{3}}{Q}, \frac{v_a}{n\delta}, \frac{L_t}{\delta}, \frac{\dfrac{Q}{\rho v_a}}{\delta^{2}}\right) \tag{2.14}$$

For the sake of simplicity the following notations are used:

$$p_1 = \frac{\rho n\delta^{3}}{Q},\quad p_2 = \frac{v_a}{n\delta},\quad p_3 = \frac{L_t}{\delta},\quad p_4 = \frac{Q/\rho v_a}{\delta^{2}}.$$

Among the specific forms of the function F, chosen during the analysis of the dependence of the experimental data (λ depending on p_1, ... p_4, on their turn, function of: n, ρ, δ, Q, v_a and L) which are given in table 2, after using the criterion of the minimum distance of theoretical data to the experimental ones - D_λ (dispersion) we have chosen the form in item 16. Some other forms were examined, too, but no other performing functions had been found, except for the one in item 16 (table no. 2). This analysis is performed on an infinite set of possible functions. Thus the specific form of the dependence of function F on the parameters p_1, p_2, p_3 and p_4 (the simplified form) is established by the author, representing the dependence of the parameter λ on the parameters p_1, ... p_4 or on some of their combinations to obtain lowest dispersion. For the β parameter a similar dependence is given.

3. Considerations on the density function and the probability distribution of the material separated through the space between rotor and counter-rotor

At point 2 of this paper it has been accepted the suggestion of using the relation (2.2) for the material density function - S_d, and, implicitly, for the probability distribution - S_s, the relation (2.3). It could be noticed that, in order to satisfy the properties of a probability distribution, the relation (2.6) should take place, between the two parameters of the relation (2.2.) for S_s, which can be also written under the form:

$$L = \frac{\ln \beta - \ln \lambda}{\lambda - \beta} \tag{3.1}$$

This condition shows that only one of the two parameters of the relation (2.2.) is missing.

At this level the working strategy becomes bifurcated, as for as, two working ways become possible:

by using the experimental data the loose parameter "A" (the relation 3.3) is determined so that the probability distribution S_s, should model "as much as possible" the experimental data, then the dependence of this parameter on the process variables occurring in the argument list of function F, is determined as in (2.14) instance; A - parameter which will be calculated by a procedure, that takes into account certain conditions of the process: $x = L \Rightarrow A = 1$.

Taking into consideration the form of the experimental curves, it is remarked that the function S_d generally presents an overall extremum within the working range [0, L] a reference point for the experiment and this extremum can be imposed on the modeling function, with some additional conditions.

We proceede for the moment with the classical analysis of minimizing the functional $F(\lambda, \beta, A)$ by the least squares method. The second way will be developed further.

$$F(\lambda, \beta, A) = \sum_{i=1}^{n} (S_s(x_i, A, \lambda, \beta) - S_s)^2$$

If, taking into account the slopes of the curves in the experimental data, it should impose that the function S_d, given by the relation (2.2.), have the bending point of coordinates (x_{Sdmax}, S_{dmax}), but the fulfilment of two more conditions besides the condition (2.6.) by the two parameters λ and β of the function is, generally impossible, the system being over determined.

Besides these observations, it can also be considered that the form (2.2) of the function S_d cannot simultaneously satisfy the condition (2.6) and the condition to have the above - mentioned bending point, by the statement that $x_{Sdmax} \in [0, L]$. As the function should be continuous and derivable in the working interval, the abscissa of the bending point should zero the first derivative of the function (2.2) depending on the threshing length - x, which results from the following relation:

$$x_{S_{d\max}} = \frac{\ln\beta - \ln\lambda}{\lambda - \beta} = L, \tag{3.2}$$

This shows that the bending point cannot be found within the working interval for the form (2.2) of the function of material density.

As a result, in order to operate with the second procedure (advantageous when the experiments are very precise as the functions found on this way fully overtake the experimental errors), the following alternative is proposed with three parameters for the function S_d:

$$S_d(x) = A(e^{-\beta x} - e^{-\lambda x}), \tag{3.3}$$

And by integrating the function (3.3) the expression for the probability distribution results:

$$S_s(x) = A\left(\frac{e^{-\lambda x} - 1}{\lambda} - \frac{e^{-\beta x} - 1}{\beta}\right), \tag{3.4}$$

The conditions for securing an extremum of the function S_d in the point (x_{Sdmax}, S_{dmax}), (experimentally indicated) and the condition (2.5) are materialized in the non linear transcendent equation system:

$$\begin{cases} \dfrac{\ln\beta - \ln\lambda}{\lambda - \beta} = x_{S_{d\max}} \\ \dfrac{e^{-\beta x_{Sd\max}} - e^{-\lambda x_{Sd\max}}}{\dfrac{e^{-\lambda L} - 1}{\lambda} - \dfrac{e^{-\beta L} - 1}{\beta}} = S_{d\max} \end{cases} \tag{3.5}$$

If the system (3.5) possesses a solution (it also remains possible to solve the problem of uniqueness), then the parameter A is calculated according to the formula:

$$A = \frac{1}{\dfrac{e^{-\lambda L} - 1}{\lambda} - \dfrac{e^{-\beta L} - 1}{\beta}} \tag{3.6}$$

Notations: $p_1 = \dfrac{\rho n \delta^3}{Q}$, $p_2 = \dfrac{v_a}{n\delta}$, $p_3 = \dfrac{L_t}{\delta}$, $p_4 = \dfrac{S}{\delta^2} = \dfrac{Q/\rho v_a}{\delta^2}$ (3.7)

With these notations the functions established on the basis of experimental data may present any of the forms given in table 2, determined by *means of the least - squares method* and the *Mathcad* programme. The functions from the criteria 1,2,3 and 4 are one variable linear partial functions and those from the criteria 6, 7, 8, 9 and 10 are linear partial functions of two variables. A certain superiority of the overall approximation, 11 is noticed. The most performing rational formula is given at den. no. 16. On the basis of the experimental data formerly obtained (during tests) some approximate forms of the rate of the curves modelling the working process may be identified. On these graphs, the functions from the criteria 1÷16 have been determined by successive tests. In order to select the best of the proposed combinations the dispersion (variance) of the theoretical data was calculated as compared to the experimental ones. The dispersion (variance) - D_λ (the mean square deviation for the n values) is calculated for the graph of the obtained function and is given by:

$$D_\lambda = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n}}$$

According to the considered approximate criterion; the rational formulas from criterion no. 16 are the best. However, the quests for increasing the precision may continue. From the multitude of tested versions it can be noticed from table 2 that the rational formulas from criterion no. 16 are the best ones. After finding λ, in a similar way β is also determined, in the form:

$$\beta = 44106.46 \frac{p_1^3 p_3}{p_2 p_4^2 \delta} + 2.76865$$

And the dispersion (variance) as:

$$D_\beta = 0{,}02455466$$

The formulas for λ and β result:

$$\begin{cases} \lambda = 3{,}135 \cdot 10^{-8} \dfrac{p_1 p_4^3}{\delta p_2^2} + 17{,}331 \\ \beta = 44106{,}46 \dfrac{p_1^3 p_3}{p_2 p_4^2 \delta} + 2{,}76865 \end{cases} \tag{3.8}$$

$$p_1 = \frac{\rho n \delta^3}{Q},\quad p_2 = \frac{v_a}{n\delta},\quad p_3 = \frac{L_t}{\delta},\quad p_4 = \frac{S}{\delta^2} = \frac{Q/\rho v_a}{\delta^2}$$

Table 2

Den. No.	**λ**	**Dispersion [D_λ]**
1.	$38.502 \frac{p_1}{\delta}$	0.20700013
2.	$0.547 \frac{p_2}{\delta}$	0.22533057
3.	$0.004457 \frac{p_3}{\delta}$	0.16572981
4.	$0.001041 \frac{p_4}{\delta}$	0.17762885
5.	$\frac{29.05 p_1 + 0.347 p_2}{\delta}$	0.18200157

6.	$\frac{15.44\, p_1 + 0.003486\, p_3}{\delta}$	0.15471791
7.	$\frac{19.971\, p_1 + 0.0007714\, p_4}{\delta}$	0.15722568
8.	$\frac{-0.248\, p_2 + 0.005733\, p_3}{\delta}$	0.16040659
9.	$\frac{-0.091\, p_2 + 0.001152\, p_4}{\delta}$	0.17687420
10.	$\frac{0.012\, p_3 - 0.001789\, p_4}{\delta}$	0.15757224
11.	$\frac{-34.59 p_1 - 0.479 p_2 - 0.129 p_3 + 0.016 p_4 + 7.623}{\delta}$	0.14328398
12.	$\frac{13.446\, p_1 - 0.16\, p_2 + 0.004435\, p_3}{\delta}$	0.15254997
13.	$\frac{19.78\, p_1 - 0.053\, p_3 + 0.0008388\, p_4}{\delta}$	0.15693625
14.	$\frac{11.809\, p_1 + 0.006654\, p_3 - 0.0007215\, p_1}{\delta}$	0.15396032
15.	$\frac{-0.332\, p_2 + 0.015\, p_3 - 0.002225\, p_1}{\delta}$	0.14783308
16.	$3.135 \cdot 10^{-8} \frac{p_1 p_4^3}{\delta p_2^2} + 17.331$	0.12690374

This can also be written under the form:

Based on the values for λ and β the parameter A is calculated from the relation (3.6):

$$A = 3{,}37 \tag{3.9}$$

By introducing A into the relation (3.4) the probability distribution of separated seeds, $S_s(x)$ may be found:

$$S_s(x) = A\left(\frac{e^{-\lambda x} - 1}{\lambda} - \frac{e^{-\beta x} - 1}{\beta}\right)$$

$$S_s(L) = 1 \tag{3.10}$$

From the relations for $S_s(x)$ below $S_l(x)$ can be found from (3.10):

$$S_d(x) = A(e^{-\beta x} - e^{-\lambda x})$$

$$\frac{dS_s(x)}{dx} = \beta S_l(x)\text{, it results: } S_l(x) = \frac{1}{\beta}\left(e^{-\beta x} - e^{-\lambda x}\right) \tag{3.11}$$

By introducing Ss(x) and Sl(x) into the relation (2.7) the probability distribution of unthreshed seeds - $S_n(x)$, may also be found.

$$S_n(x) = 1 - S_s(x) - S_l(x)$$

$$S_n(x) = 1 - A\left(\frac{e^{-\lambda x} - 1}{\lambda} - \frac{e^{-\beta x} - 1}{\beta}\right) - \frac{1}{\beta}(e^{-\beta x} - e^{-\lambda x}) \tag{3.12}$$

Having the values for $S_n(x)$, $S_l(x)$ and $S_s(x)$, from the rotation (2.8) the exhausting losses - p_{ev}, can be easily found, which will be:

$$p_{ev} = \left(1 - S_s(L)\right). \tag{3.13}$$

The aim of this modelling is to minimizing the losses in the conditions of performing an as good as possible separation of ears out, namely in a percentage over 99%.

4. Probability distribution (S_s) and density function of separated seeds (S_d)

From the 16 versions of the functions λ (indicated in table 2), from physical reasons, first, but also for accuracy reasons, (as the precision estimator show), the last version was selected with the denomination number 16:

$$\lambda = 3{,}135 \cdot 10^{-8}\,\frac{\rho n^3 S^3}{Q\delta^2 v_a^2} + 17{,}331,\quad \beta = 44106{,}46\,\frac{\rho^3 n^4 \delta^{12} L_t}{Q^3 S^2 v_a} + 2{,}76865 \tag{4.1}$$

According to the relation (3.4) the probability distribution of separated seeds has the form:

$$S_s(x) = A\left(\frac{e^{-\lambda L} - 1}{\lambda} - \frac{e^{-\beta L} - 1}{\beta}\right), \qquad (4.2),$$

where:

$$A = \frac{1}{\dfrac{e^{\;\lambda L}\quad 1}{\lambda}\quad \dfrac{e^{\;\beta L}\quad 1}{\beta}} \tag{4.3}$$

The density function represents the derivative of the probability distribution as compared to variable *x*:

$$S_d(x) = A\left(e^{-\beta L} - e^{-\lambda L}\right) \tag{4.4}$$

The relation (2.1) connects the input flow, the processed material density, the feeding speed (rate) and the surface (area) of the feeding opening, which should be considered as given by: $Q = \rho S v_a$.

By using the relation (2.1) the flow rate can be removed from the relations (4.1). Thus the expressions (4.5) are obtained for the parameters of the function λ and β occurring in the expressions of the probability distribution and the density function.

$$\lambda = 3{,}13510^{\;8}\,\frac{n^3 S^2}{\delta^2 v_a^3} + 17{,}331,\quad \beta = 44106{,}46\,\frac{n^4 \delta^{12} L}{S^5 v_a^4} + 2{,}76865 \tag{4.5}$$

It is noticed that in this way the dependence on density ρ is removed and that if generally S = const. is considered (from construction reasons of the threshing apparatus) then the parameters λ and β remain to only hang on n, δ, v_a and L.

5. Determination of the other characteristic functions of the threshing and separating process

For reaching the final stage of the theoretical - empirical modelling of the threshing process, the stage of studying of the possibilities of optimizing the working process the functions should be found. For this process the main objective is to minimize the losses. The threshing and separating losses are the limit of the probability distributions of unthreshed seeds S_n and the free seeds within the threshing area S_l.

$$p_{tr} = \int_0^L S_n(x)\,dx; \quad p_s = \int_0^L S_l(x)\,dx; \quad p_{ev} = \int_0^L (1 - S_s(x))\,dx \tag{5.1}$$

where the functions S_n and S_l are also defined by the relation:

$$S_s(x) + S_l(x) + S_n(x) = 1 \tag{5.2}$$

The relation cannot supply by itself both function Sn and Sl in the paper (4) being given a relation connecting the derivative of the function Sn at function Sl. This relation is connected to the form of the probability distribution considered for the process (slightly different from the function considered in the present paper). In the spirit of this relation the following relation can also be considered:

$$\frac{dS_s(x)}{dx} = kS_l(x) \quad \text{or} \quad \frac{dS_s(x)}{dx} = \beta S_l(x) \qquad 5.3) \approx (\Re)$$

As long as between the probability distribution of separated seeds and the density function of separated seeds the relation exists:

$$\frac{dS_s(x)}{dx} = S_d(x), \tag{5.4}$$

a linear relation between the functions S_l and S_d results:

$$S_l(x) = \frac{S_d(x)}{k} \tag{5.5}$$

Then, from (6.2) it results:

$$S_n(x) = 1; \qquad S_s(x) = \frac{S_d(x)}{k} \tag{5.6}$$

The problem is further solved if the constant k is known. Thus:

$$\begin{cases} p_s = \dfrac{S_s(L)}{k}, \\ p_{ev} = L - A\left[\left(\dfrac{1}{\beta} - \dfrac{1}{\lambda}\right)L + \dfrac{e^{-\beta L} - 1}{\beta^2} - \dfrac{e^{-\lambda L} - 1}{\lambda^2}\right], \\ p_{tr} = p_{ev} - p_s \end{cases} \tag{5.7}$$

It is noticed that the quantity of free seeds in the straw has a high value in the first part of the threshing apparatus (at the beginning of separation), due to the fact that in the first zone of the threshing apparatus the threshing operation is mainly performed after what the quantity diminishes when entering the apparatus separating area.

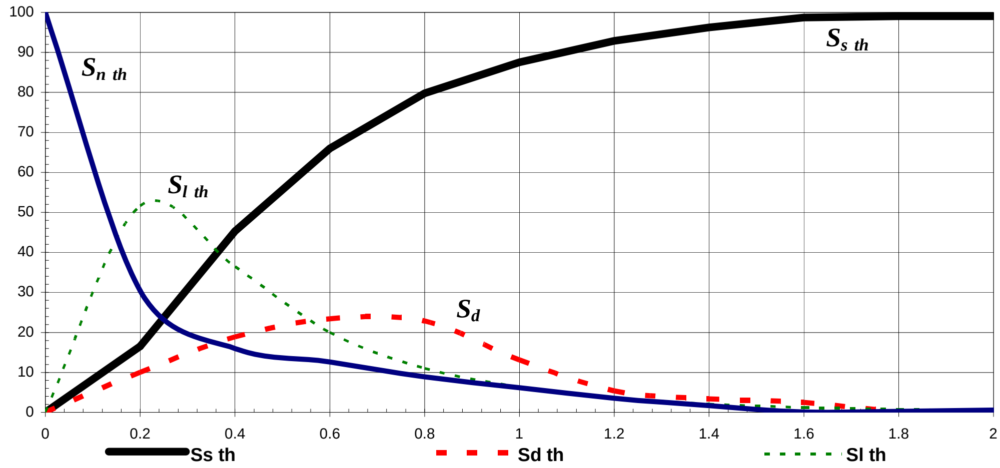

Fig. 5.1 - Variation of the percentage of separated seeds (*Ss*), unthreshed seeds (*Sn*) free seeds (*Sl*) and density function (*Sd*) on the rotor length, *L* (for the value mean in experiments, theoretically determined), where: n = 900 rpm = ct; Q = 0,838 kg/s = ct; v_a = 0,13235 m/s = ct

8. Conclusions

Taking into consideration the difficulty of creating a mathematical model for the threshing and separating process which should take into account all the input parameters which directly or indirectly influence this process, to model the process well enough, that no major deviations from the real process should occur, the model should not be complicated too much; for performing this modeling there were taken into account only 7 out of the most important input parameters: Q (kg/s), n (rpm), δ (m), ρ (kg/cu.m), v_a (m/s), L_t (m) and S (sq.m).

In order to control the modelling process it was also established what it was to be obtained (quantified), namely the output parameters, in a first stage having: S_s - the probability distribution of separated seeds, S_d - the density function of separated seeds, S_l - the probability distribution of free seeds in the threshing area and S_n - the probability distribution of unthreshed seeds, after their determination, the other output parameters being to be established, which quant size the quality of the threshing and separating process: p_{ev} - value of exhausting losses.

In order to obtain an as real as possible modelling of the threshing and separating process there was performed a dimensional analysis of the considered input parameters, so that it was obtained the dependence among parameters, but especially the dependence relation between the λ. and, respectively β coefficients depending on the parameters taken into consideration and the dependence one between λ and β.

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