Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)
2008, 4 (4), 349 - 354

Eulerian and Weibullean Functions Used for Simulation the Seeds Separation Process on the Sieves of the Cleaning Systems

Gheorghe VOICU, Constantin TARCOLEA, Tudor CASANDROIU
Politehnica University of Bucharest, Romania
ghvoicu_2005@yahoo.com

Abstract: The separation process of the seeds is influenced by many random factors, because there is a natural variability of the studied phenomena. Therefore for the simulating process of the seeds separation at cleaning system sieves of the cereal harvesters can be described accordingly by means stochastic models. The main objective of the paper is to prove that eulerian and weibullean functions are adaptive distributions for describing of evaluation of grain cleaning, because these sets of elements contain symmetric and skewed functions. The presented models allow simulating and prediction of the separation processes of seeds at cleaning system sieves on length and can made the evaluation of the seeds losses from the cleaning system.
Key words: harvesting combine, cleaning system, seeds separation, eulerian distribution laws

INTRODUCTION

The cleaning system is a very important equipment of a combine harvester because its performances influence the performances of the entire combine. The separation process takes place on the sieves of the cleaning system thanks to the oscillation movement of the sieves and of the ascending air flow, which permeates the layer of material *(Baumgarten, 1987; Voicu, 1996; Zaika, 1975)*.

The seeds separation process has a natural variability and depends on many random factors. The particles movement is random, due to the heterogeneity of physical properties of material and of the seeds. Therefore the modelling of the seeds separation process on sieves of a cleaning system can be based on stochastic theory (*Balascio et al., 1987; Tarcolea et al., 2008; Voicu et al., 2004, 2006, 2008*).

Many authors studied the cleaning separation process on the sieves, made experimental and theoretical researches, and proposed different deterministic and stochastic mathematical models *(Casandroiu et al., 2008, Schreiber et al., 2003; Voicu et al., 2004, 2005, 2006, 2007, 2008)*.

The mathematical model proposed by Bottinger, developed from the model of Kutzbach, provides information about the quantity of seeds remained on the sieve (*Schreiber et al., 2003)*. *According to Voicu et al. (2004, 2006)*, it was constructed a Rosin-Rammler type relation and a logistic function, as a stochastic model for describing the seed separation process on sieve.

However, the history of Rosin-Rammler models goes back earlier, to the weibullean and eulerian functions. Our experimental researches show that the distributions can be symmetric or skewed, left or right. In the papers *Tarcolea et al. (2008) and Voicu et al. (2008*) were presented some Weibull and Euler models too. The present paper analyses same of these laws and focuses the study of new adequate weibullean and eulerian models, because these functions are adaptive for describing of evaluation of grain cleaning, for the given conditions, for each concrete case. These models are used at the prediction seeds losses at cleaning system.

MATERIALS, METHODS and PROCEDURES

The experiments were conducted with wheat pile material on laboratory stand under simulation of different work conditions. The parameters of interest - which were modified during experiments, in order to determine their influence on the separation process - are: specific supply flow rate q; air flow velocity at the ventilator exit v_a; blinds opening D_j; straw parts per seeds ratio pp/s; oscillation frequency f. Our experimental stand sieve has the length of 1.2 m and the seeds were collected under the sieve in eight compartments, each with a length of 0.15 m. The seed losses were collected in an additional compartment *(Voicu et al., 1996)*. The parameters values and experimental results are presented in the table 1.

The separation process of seeds on sieve length, executed by the cleaning system of the harvesting combines, can be evaluated by separation intensity, which is defined as the separated seeds quantity on length unit, in a section x from the beginning of the sieve, in percentage, in comparison with the whole quantity separated by sieve, *(Voicu et al., 2008)*.

The canonical weibullean and eulerian functions have usually unbounded ranges, while the sieve length in our case is the bounded interval [0.075; 1.275]. In the present paper we proposed the adequate models for this case, which can be easily adapted in the similar situations.

"The English biometrician Sir Francis Galton (1822 – 1911) fitted a straight line to the plot of the heights of sons versus the heights to their father in his studies of inheritance, in particular of the law of universal regression" *(John, 1990)*. It is known that the regression coefficients are generally used to describe fitting curves to observed data.

The distribution analysis of experimental data points for the separation intensity on upper sieve length of the cereal combine harvester's cleaning system indicates that curve graphs have a bell shape with a degree of asymmetry *(Heike et al., 2000; Voicu et al., 2008)*.

Table 1. Separated seeds percentage (separation intensity) on sieve length

No. sample	Sieve length from which seeds are collected *x* (m)								
	0.075	0.225	0.375	0.525	0.675	0.825	0.975	1.125	1.275
1	*f = 280 osc/min; q = 0.15 kg/dm·s; v_a = 8 m/s; D_j = 12.5 mm; pp/s = 0.24*								
	2,7	9,6	33,5	36,2	13,2	3,6	0,8	0,2	0,2
2	*f = 280 osc/min; q = 0.10 kg/ dm·s; v_a = 8 m/s; D_j = 11 mm; pp/s = 0.25*								
	2,5	8,3	25,3	26,2	20,8	10,8	4,2	0,5	1,4
3	*f = 280 osc/min; q = 0.15 kg/ dm·s; v_a = 8 m/s; D_j = 11 mm; pp/s = 0.27*								
	1,7	6,2	23	27,1	22	12,6	5,6	1	0,8
4	*f = 280 osc/min; q = 0.20 kg/ dm·s; v_a = 10 m/s; D_j = 11 mm; pp/s = 0.27*								
	4,2	12	21,6	19,9	19,5	14,5	7,4	0,7	0,2
5	*f = 190 osc/min; q = 0.10 kg/ dm·s; v_a = 8 m/s; D_j = 11 mm; pp/s = 0.25*								
	17	42,8	30,5	7,1	1,7	0,45	0,25	0,1	0,1
6	*f = 240 osc/min; q = 0.10 kg/ dm·s; v_a = 8 m/s; D_j = 11 mm; pp/s = 0.25*								
	8,3	23,5	41,8	20,9	4,2	0,8	0,35	0,1	0,05
7	*f = 335 osc/min; q = 0.20 kg/ dm·s; v_a = 10 m/s; D_j = 11 mm; pp/s = 0.252*								
	0,2	0,8	3,1	13,9	22,6	20,8	16,8	15,8	6
8	*f = 280 osc/min; q = 0,15 kg/dm·s; v_a = 6,2 m/s; D_j = 12,5 mm; pp/s = 0,25*								
	3,3	10	32,7	35,5	13,1	3,8	0,7	0,2	0,7
9	*f = 280 osc/min; q = 0,15 kg/dm·s; v_a = 10 m/s; D_j = 12,5 mm; pp/s = 0,25*								
	2	7,7	33,9	36,5	14,5	3,6	1	0,3	0,5
10	*f = 280 osc/min; q = 0, 50 kg/dm·s; v_a = 5 m/s; D_j = 9 mm; pp/s = 0,27*								
	6,7	18	28,7	21,3	14	5,2	3,4	2,4	0,3
11	*f = 280 osc/min; q = 0,1 kg/dm·s; v_a = 5 m/s; D_j = 9 mm; pp/s = 0,26*								
	4,8	11,7	23,2	18,7	17,3	11,2	10,3	2,5	0,3
12	*f = 280 osc/min; q = 0,15 kg/dm·s; v_a = 5 m/s; D_j = 9 mm; pp/s = 0,27*								
	4,5	10,9	17	22,5	17,6	12,3	10	4,9	0,3
13	*f = 335 osc/min; q = 0,10 kg/dm·s; v_a = 8 m/s; D_j = 11 mm; pp/s = 0,25*								
	0,9	2,7	10,5	15,6	19,8	20,9	20	7,1	2,5

These profiles can be described by means of different distribution laws.

The parameters of the proposed functions were estimated from the experimental data and the computations were carried out in Microcal Origin.

In the present paper we propose the following continuous probability laws *(John, 1990; Tarcolea et al., 1989)*:

$$f(x) = a(x - 0.075)^{b}\, e^{-c\,(x-0.075)^{b+1}} \qquad (1)$$

(an adaptive proposal of weibullean distribution)

$$f(x) = a\,\frac{x^{b}}{(c\,x + d)^{m}} \qquad (2)$$

(an eulerian distribution of beta type)

$$f(x) = a \cdot x^{b} \cdot e^{-c\,x} \qquad (3)$$

(an eulerian distribution of gamma type)

$$f(x) = \frac{a}{x} \cdot e^{-b(\ln x - c)^{2}} \qquad (4)$$

(the lognormal distribution)

$$f(x) = a \cdot e^{-b(x-c)^{2}} \qquad (5)$$

(the normal distribution)

In comparison with the canonical forms, we made adaptive models for the cases of bounded intervals.

The lognormal and normal laws can be considered as eulerian distributions. In the equations (1-5), f(x) is the intensity separation (%), at the x section, from the beginning of the sieve, and the unknown coefficients (a, b, c, d, m) are determined based on the experimental data using the nonlinear regression.

RESULTS and DISCUSSIONS

For each experimental sample from table 1, the seeds separation intensity on the sieve length was graphically represented; the regression curves for the proposed models (eq.1-5) are provided in the figure 1.

In table 2, the regression coefficient values (a, b, c, d, m) and the correlation coefficients (χ^2, R^2) are presented for the analyzed functions.

In some cases, the observed values are positively skewed, in other cases have a small variance and hence present a big degree of peakedness, compared to the normal distribution *(Voicu et al., 2008)*. An explication for this variability of the samples is the diversity of work conditions and the natural variability of the physical properties of the materials. In other words, it must choose the adequate model for practical cases.

Table 2. The coefficients values a, b, c, d, m obtained through testing relations 1 – 5 with experimental data and correlation coefficients χ^2 and R^2

	Pr. 1	Pr. 2	Pr 3	Pr 4	Pr 5	Pr 6	Pr 7	Pr 8	Pr 9	Pr 10	Pr. 11	Pr. 12	Pr. 13
The weibullean model (eq.1)													
a	576.88	173.39	171.95	95.63	446.19	603.45	79.365	538.10	597.20	143.89	80.494	81.050	91.141
b	2.115	1.468	1.569	1.07	1.056	1.648	2.072	2.069	2.171	1.008	0.913	1.051	1.927
c	13.018	4.825	4.538	3.110	16.811	16.780	1.644	12.460	13.145	5.158	2.845	2.690	2.068
χ^2	2.137	3.056	2.251	6.183	48.385	11.737	6.228	2.832	2.286	9.554	8.901	5.502	4.731
R^2	0.992	0.979	0.984	0.934	0.854	0.959	0.938	0.989	0.992	0.926	0.887	0.919	0.947
The eulerian – beta model (eq.2)													
a	0.059	0.106	0.089	0.153	0.204	0.083	0.143	0.062	0.052	0.154	0.054	0.168	0.043
b	12.109	9.059	9.811	4.842	3.842	9.356	15.848	11.844	12.784	5.071	3.604	4.648	8.419
c	0.546	0.504	0.497	0.397	0.618	0.576	0.506	0.544	0.548	0.463	0.293	0.382	0.315
d	0.339	0.335	0.340	0.384	0.273	0.335	0.348	0.340	0.337	0.357	0.454	0.387	0.498
m	29.987	22.280	23.678	15.449	12.554	25.678	30.325	29.479	31.141	16.031	16.597	14.671	27.854
χ^2	15.668	5.099	3.670	14.585	15.661	26.812	4.908	16.215	12.122	10.842	11.356	10.773	17.641
R^2	0.961	0.976	0.983	0.896	0.969	0.937	0.967	0.957	0.971	0.944	0.904	0.894	0.868
The eulerian – gamma model (eq.3)													
a	$6.5\cdot10^{8}$	$3.1\cdot10^{5}$	$5.0\cdot10^{5}$	$5.2\cdot10^{3}$	$3.2\cdot10^{4}$	$1.7\cdot10^{8}$	$2.9\cdot10^{5}$	$3.3\cdot10^{8}$	$2.0\cdot10^{9}$	$9.9\cdot10^{3}$	$2.3\cdot10^{3}$	$3.2\cdot10^{3}$	$7.9\cdot10^{4}$
b	9.127	5.335	5.803	3.059	2.578	7.374	7.562	8.756	9.814	2.929	2.557	2.927	6.048
c	20.736	11.218	11.525	6.645	12.131	21.325	9.739	19.950	21.951	8.082	5.823	6.016	8.624
χ^2	3.952	2.075	1.051	6.814	4.952	11.267	3.712	4.887	1.687	4.856	6.487	4.976	9.510
R^2	0.985	0.985	0.993	0.927	0.985	0.961	0.963	0.981	0.994	0.962	0.918	0.927	0.894
The lognormal model (eq.4)													
a	17.796	14.244	14.977	11.747	10.574	15.863	18.288	17.251	18.605	11.695	11.145	11.540	15.884
b	4.598	2.796	3.042	1.762	1.347	4.098	3.734	4.377	5.089	2.088	1.615	1.685	2.961
c	-0.738	-0.610	-0.563	-0.547	-1.319	-0.972	-0.148	-0.738	-0.727	-0.783	-0.557	-0.473	-0.222
χ^2	8.500	3.577	2.554	10.967	12.687	12.475	3.246	9.475	4.866	8.020	8.687	8.396	13.204
R^2	0.968	0.975	0.982	0.862	0.961	0.956	0.968	0.963	0.982	0.938	0.890	0.877	0.852
The normal model (eq.5)													
a	39.741	27.738	27.764	22.331	43.986	40.646	22.566	38.617	40.409	26.903	20.851	20.578	22.275
b	23.659	10.896	10.819	6.352	27.081	24.166	6.436	22.649	24.460	10.493	5.521	5.509	6.534
c	0.463	0.520	0.548	0.537	0.261	0.364	0.825	0.462	0.468	0.417	0.522	0.562	0.758
χ^2	1.240	3.941	3.773	3.565	0.408	2.525	7.154	1.594	1.865	4.078	8.098	2.920	4.477
R^2	0.995	0.972	0.974	0.962	0.999	0.991	0.929	0.994	0.993	0.968	0.897	0.957	0.950

From the analysis of values in table 2, it results that the weibullean and eulerian laws (eq. 1-3) have a better goodness of fit with experimental data; the correlation coefficients have in most cases good values ($R^2 \geq 0.919$ for weibullean and $R^2 \geq 0.927$ for eulerian models), and similarly, the graphs of these laws are much closer to experimental data for many cases (figure 1).

The seeds losses were predicted for different sieve lengths, the last collected interval has the mean at 1.125 m from the beginning of the sieve. The computations were carried out in MathCAD, based on the calculus of the integrals of the obtained distribution functions, and the results are presented in table 3.

The density probability functions were before normalized.

Perhaps, for these predictions, the skewed of the curves is better estimated with eulerian laws (eq.2 and eq.3, see figure 1).

Table 3. Experimental data and predicted values (eq.1-5) of seeds losses (%)

No. Sample	1	2	3	4	5	6	7	8	9	10	11	12	13
Observed data	0.20	1.40	0.80	0.20	0.10	0.05	6.00	0.70	0.50	0.30	0.30	0.30	2.50
Weibull (eq.1)	0.00	0.38	0.51	2.16	0.00	0.00	9.71	0.00	0.00	0.28	4.94	3.17	6.45
Beta (eq.2)	0.64	2.20	2.55	3.86	0.34	0.25	10.61	0.68	0.64	1.76	3.93	4.87	8.44
Gamma (eq.3)	0.06	1.24	1.50	3.23	0.03	0.01	10.69	0.08	0.05	1.09	3.51	4.25	8.21
Ln-Norm (eq.4)	0.33	2.12	2.37	3.97	0.41	0.07	10.63	0.38	0.25	1.51	4.04	4.94	8.64
Normal (eq.5)	0.00	0.22	0.33	1.46	0.00	0.00	9.30	0.00	0.00	0.06	1.77	2.33	6.39

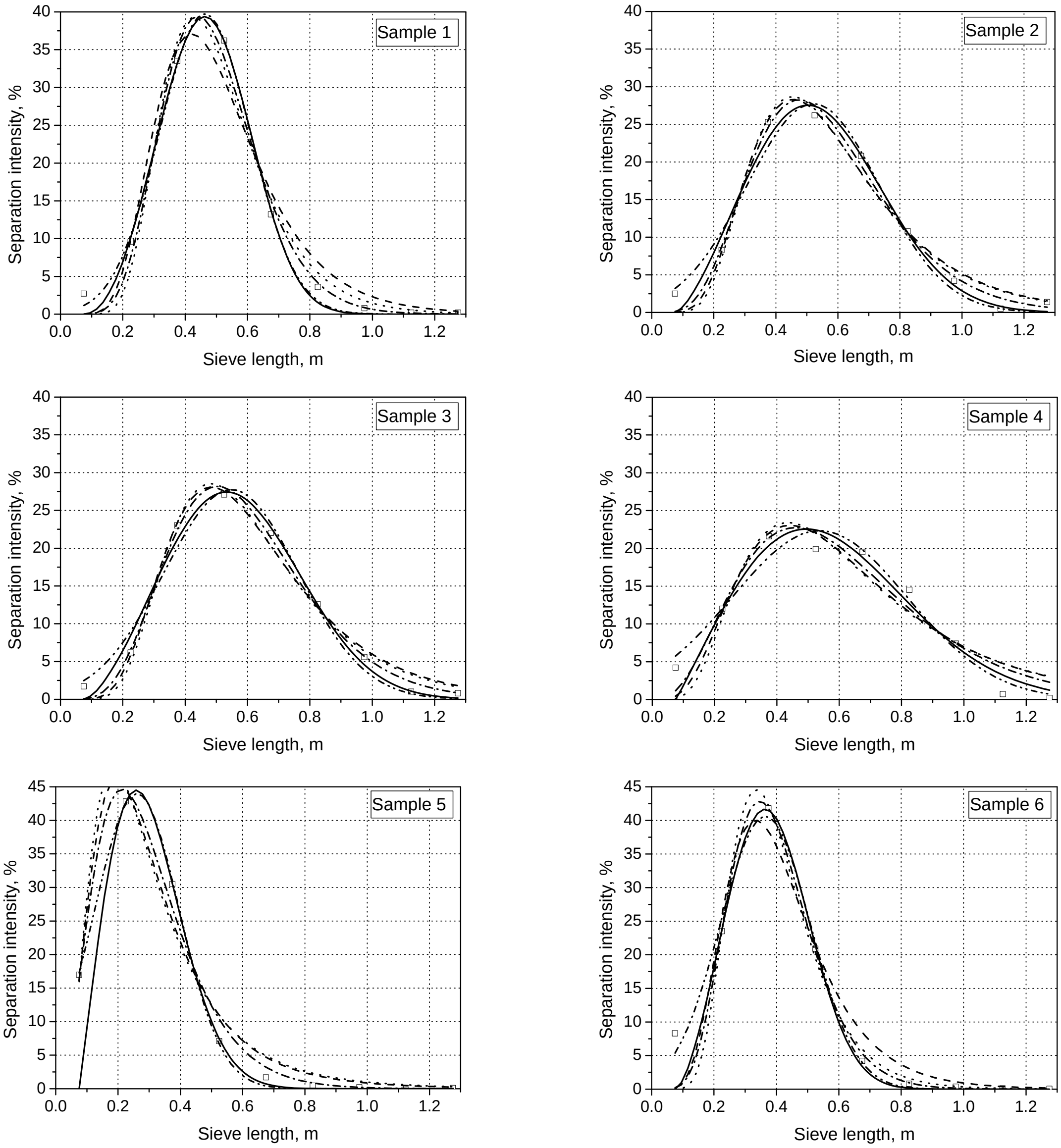
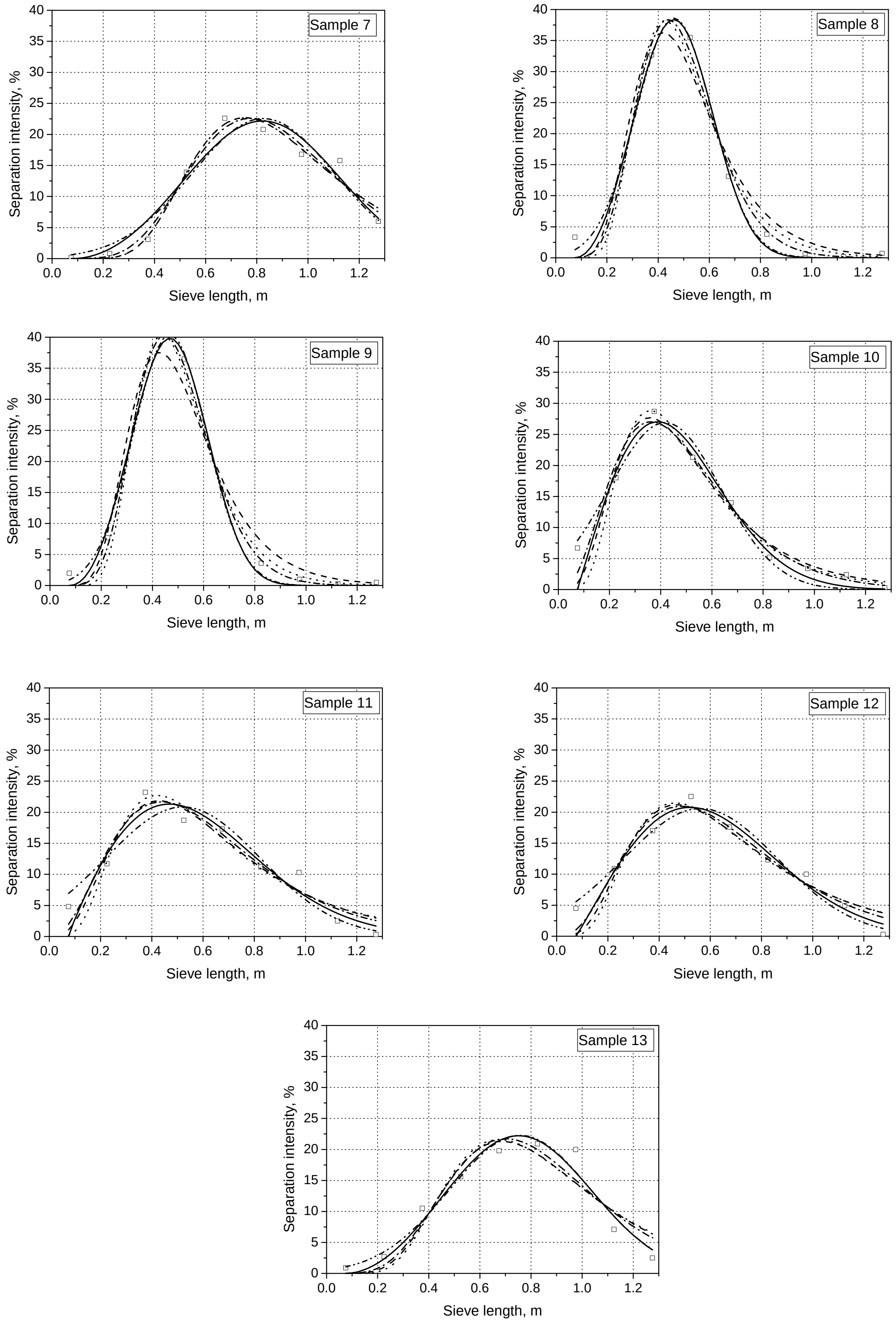


Figure 1. Intensity variation of seeds separation, on sieve length, for meaningful experiments and different values for main parameters of the working process

□ – experimental points; —— Weibull distribution (eq.1); – – – – beta distribution (eq.2); — · — gamma distribution (eq.3); · · · · · · log-normal distribution (eq.4); — · · — normal distribution (eq.5)

Figure 1. (continuation)



CONCLUSIONS

In the paper it was proposed adaptive stochastic models and it was analysed classical laws for describing of evaluation of grain cleaning for working concrete cases. It results that for different cases agree different functions. The models have a good fitting to experimental data as shown by the chi-square and correlation coefficients. These results can be useful both in design work and in the practice, allowing the prediction of the seeds losses for the cleaning system of the harvesting combines.

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