PARTICLE SIZE DISTRIBUTION OF WHEAT GRIST FRACTIONS IN PLANSIFTER COMPARTMENTS OF A FIVE BREAKS ROLLER MILL SYSTEM

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Abstract. In wheat milling, it is particularly necessary that the grist particle size-distribution entering and exiting each plansifter compartment of the wheat mill to be determined so that the appropriate geometrical characteristics of flutes, grinding rolls and their functional parameters can be chosen and the characteristics of the sieves braids to be established to optimize flour, middling, and semolina yield and quality of them. The paper presents the particle size-distribution of wheat going through each break, in a five-break roller mill system with a capacity of 4.2 t/h and equipped with a semolina sorting compartment (divisor). The particle size distribution data where fit to the Rosin-Rammler distribution equation.

Keywords: wheat milling, grist, plansifter compartment, flour, semolina, particle size distribution, Rosin-Rammler function

1. INTRODUCTION

Wheat is one of the most industrially-processed grains for human consumption. In the milling industry, wheat is processed using roller mills to obtain, primarily flour, but also other products of value including, bran, germs and possibly semolina.

In the milling plants, the wheat seeds go through several breaks to be gradually ground, so that the highest degree of endosperm flour extraction can be achieved, with the least grinding of the seed's shell (bran). In each break a certain percentage of flour of different qualities are extracted. These are combined to obtain homogeneous flour, well-suited for end-uses, e.g. bakery. Semolina, as an intermediate product of grist, consists of clean endosperm particles or particles with a low percentage of bran. The product is reintroduced into the grinding process by means of fluted or smooth- surfaced roller mills. These particles are ground until their size is reduced to that of flour particles. As the particles of the semolina are ground, the different percentages of flour and shell (bran) are removed from the process. The stresses that the seeds and wheat particles are subjected to are due to the characteristics of the surface of the grinding rolls and their flutes. Grinding rolls and flutes, with different geometric characteristics are used for each break/stage of the milling process which affects the compression, shearing, crushing, cutting, friction and collision forces on the kernels [1].

The differential speed of the grinding rolls exerts a certain influence on the mechanics of the material grinding, the best ratio of rotations/speeds of the two grinding rolls being of about 2.5 [2].

The particle distribution of the ground material at each break is varied, depending on working regime used for each pair of grinding rolls, as well as the physical characteristics of the wheat seeds. Therefore, the grinding conditions, type of grinding equipment, velocity of working parts can affect this size distribution of the grist [3].

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To ensure that each pair of grinding rolls in the technological flow processes the material as homogeneous as possible and with the most uniform particles size, after each step of grinding, the grist products goes through a sorting operation in a sifting compartment of a plansifter. This operation is completed by the cleaning of semolina in the semolina machine and/or processing it in a bran finisher. The selection of the sieve braid type (wire or textiles) and of the mesh size inside the plansifter compartments depends on the desired particle size of ground product at each break. Also, even a certain fraction obtained from a sifting frame package in the plansifter compartment presents a different particle size distribution with particles sizes ranging between the sieve with larger mesh size which has sifted them and those with smaller mesh size over which has passed.

The size distribution of the grist products passing over the sieve affects the grinding performance by the next pair of grinding rolls.

The particle size distribution of the ground material has been the subject of several studies published in the literature [1-6]. The determination of the particle size distribution is performed, as a rule, with sieve shakers equipped with overlapping sieves, the sieve mesh sizes are selected, so that a percentage of the material of about 5–10 % remains on the top sieve. The following sieves, in each of mills break stages, are chosen such that mesh aperture dimensions are progressively smaller by a factor of approximately $\sqrt{2}$.

The estimation of the particle size distribution in the mixture analyzed is quantified on the basis of the cumulative weights of the fractions passing through the shaker sieve holes or being rejected.

The mathematical expression of the particle size distribution of one granular mixture is based on distribution laws commonly used to describe naturally occurring phenomenon [5, 6]. Voicu et. al [7] used Schuhman, Rosin–Rammler and the two-parameter logistic cumulative-type distribution functions to characterize the distribution by size of the material that enters and leaves the wheat grinding process in roller mills. All three laws yielded very good correlations with the experimental data.

Voicu et al. [8] fit the data to gamma, generalized gamma, delayed gamma and Weibull distributions. They found the best correlations were given by the normal and gamma functions which showed values of the correlation coefficient of $R^2 \geq 0.92$.

Despite these excellent correlations with prediction equations, the particle size distribution analysis of a granular mixture by the sifting method introduces errors into the estimation of real values. The errors are quite serious, as indicated by Igathinathane et al. [5], because of the parameters chosen for analysis: oscillations frequency of the sieve shaker, test time, grinding of some particles by friction with the sieve wire mesh or impact against its walls, electrostatic load of particles etc.

In a milling plant, the transformation of the wheat into flour takes place in two technological phases: the break phase and the grinding (reduction) phase [1, 8, 9].

Each of these phases has a cluster of roller mills for milling and a cluster of plansifter compartments for sorting of the grist. In the break phase the mill rolls have a fluted surface, while for the size reduction of semolina particles are used mill rolls with a smooth surface.

In our paper is analyzed the break phase of a mill with a capacity of 4.2 t/h and we intend to present synthetically the particle size distribution of the fraction resulting from sifting and sorting in each plansifter compartment during the wheat break phase in a milling plant with a capacity of 4.2 t/h. The second objective is to evaluate how well the Rosin-Rammler equation fits the data obtained.

2. MATERIALS AND METODS

The flow diagram of the wheat breakage process in the above-mentioned milling plant is shown in Figure 1.

In break phase, the grinding flow diagram includes six stages of which five are fitted with break machines (one pair of grinding rolls on every machine) and one with only screen sieves for classifying grist (divisor). Also, the milling system includes two semolina machines for cleaning and classifying the grist fractions with a high content of endosperm, and three bran finishers for recovering the endosperm from the fractions with high bran content.

As a characteristic of the breakage phase, the six plansifter compartments have a relatively large number of sieve groups (with the same characteristics of braid) for sifting the refusals which are made up of products resulted from grinding seeds and broken seeds by means of fluted rolls in the grinding equipment.
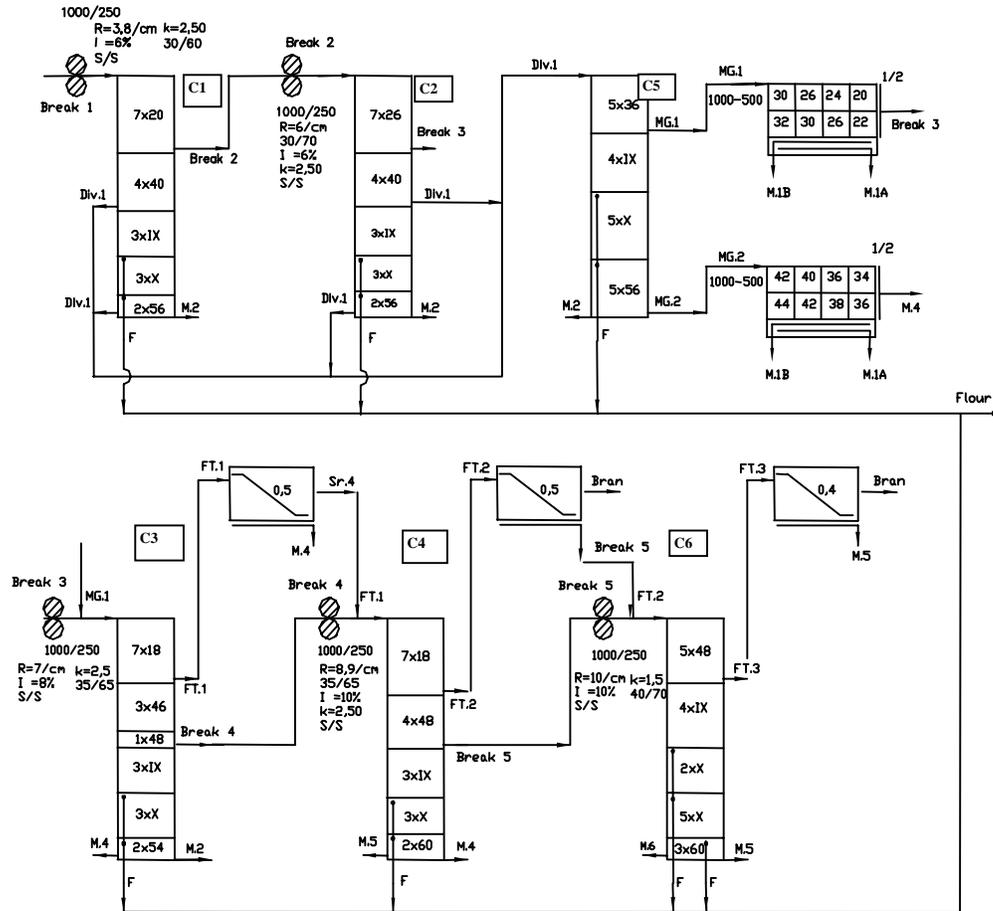

Fig. 1. The flow diagram of the wheat breakage phase in a milling plant with the capacity of 4.2 t/h:
C1–C6—plansifter compartments; Break 1–5—break rolls; DIV1—divisor (sorting compartment); MG1,
MG2—semolina machines; FT1–FT3—bran finishers; M1A, M1B, M2–M6—reduction rolls; F, F', F"—flour,
[7].

All the plansifter compartments have a first sieve group, with metal braid whose holes are more widely-opened, depending to the distance between the two break rolls which are before the compartment and which retain and eliminates the largest size particles from the grist mixed (refusals and semolina).

These fractions are directed either toward another break rolls pair or to a MG semolina machine (in the case when the first refusal consists of endosperm particles with a low adherent bran content – the case of the DIV1 divisor-sorter, compartment C5), or to a bran finisher (when the fraction consists of bran foils on which a small percentage of endosperm remained). As one can see from the study of the flow diagram, the highest quantity of semolina is obtained in the first two technological stages (Break 1 and Break 2), from these fractions that are sorted in the DIV1 divisor and then cleaned in the semolina machines (MG1, MG2), in order that to the next phase (reduction stages) to obtain a high-quality flour.

Under the first sieve group, of the first four plansifter compartments (C1 - C4), is a second sieve group for sifting a second refusal made up of the endosperm particles (semolina). The central sieve groups, to all the six compartments (noted by Roman numerals), are intended for sieving the flour that is extracted from the remaining material which is submitted for reduction and sorting (sieving) until the entire particle mixture is divided into flour and bran. The flow diagram presented does not provide for the possibility of wheat germs extract, but it can extract up to 2% semolina, to the detriment of the best quality flour.

The last sieves package from the five breaks provided with pairs of grinding rolls (C1-C4,C6), consists of two plansifter frames with a large number of threads that separate and extract, from the original mixture, the endosperm particles of relatively small sizes (dusts) that are directed toward the passages of the smooth-surfaced reduction rolls (M2, M4, M5 and M6).

According to milling industry specific regulations, on flow diagram (Figure 1) are written the grinding rolls characteristics: length, diameter (e.g. 1000x250), number of flutes per centimeter and their inclination (e.g. 7/cm, I = 8% respectively), flute angles (e.g. 35/65), arrangement of flutes (e.g. S/S – sharp to sharp), speeds ratio (e.g. k = 2.5), but also the characteristics of fabrics used to plansifter sieves (e.g. 3x46 – 3 sieves with 46 threads on an inch or sieves 3xX for flour), or to the semolina machines (e.g. 40, which is also the number of threads per inch) or to bran finishers (e.g. 0.5 – orifice size).

The sieves at the top of the plansifter compartments are provided with wire fabric because they sort broken grains of relatively large sizes (which would very soon wear out and deteriorate the textile braid), while the flour sieves and the sieves of the bottom pack are made of plastic or textile braid. Lately, textile braids have been replaced by plastic braid. In accordance with the specialized literature, for the technological diagram of the milling plant analyzed, the equivalence between the mesh number and its mesh size, as specified in the diagram, is presented in Table 1.

Table 1. Equivalence between the mesh number and sizes of holes

Mesh number	18	20	26	36	40	46	48	50	54	56	60	VIII	IX	X	XI
Mesh size (mm)	1.170	1.050	0.780	0.520	0.470	0.390	0.370	0.350	0.320	0.310	0.280	0.180	0.170	0.150	0.130

Note: Mesh number is the number of threads per inch or flour sieve number.

For the grain size analysis of the material fractions in the plane sieve compartments we used samples of 100 grams collected from the input and outputs, respectively, of each plansifter compartment. They were sieved on a set of 5 overlapping sieves of different size holes mounted onto a sieve shaker (VAPO model – made in Czech Republic), driven in a plane circular motion at a controlled speed of 120 rpm for 3 minutes. Casandroiu et al. [4] and Voicu et al. [10] present the work methodology in detail. The sieving analysis and the choice of sieves for the analysis were performed in conjunction with the methodology of work (described in the introduction chapter) in the specialized literature for analyses of this kind [11].

Based on the results obtained from the sieving analyses performed with the sieve shaker, we tested, by nonlinear regression analysis using the Microcal Origin program ver.7.0, the correlation of the experimental data with the Rosin-Rammler distribution law, for the cumulative percentage of material separated by the holes of the shaker sieves.

The Rosin-Rammler distribution law, used in the regression analysis of the cumulative percentage of the material sieved through the shaker sieves T(m), and the related experimental data is given by the relationship:

$$T(m) = 100 \cdot \left(1 - e^{-b \cdot m^n}\right) \tag{1}$$

where: m is mesh size of shaker sieves; b and n – experimental coefficients.

Knowing the percentages of the material that has remained unseparated on each sieve of the classifier, we can determine the mean particle size of the mixture analyzed, using the relationship:

$$d_m = \frac{\sum p_i \cdot c_i}{\sum p_i} \quad [mm] \tag{2}$$

where: p_i is the percentage of the material on the i sieve of the shaker (i = 0, 1, 2,… 5); $\Sigma p_i = 100$ - is the amount of material percentages on the sieves; c_i - the particle mean dimension of each intermediate fraction, considered as the arithmetic mean of the side of the sieve holes which expresses the respective fraction ($c_i = (m_i + m_{i+1})/2$). As for the top sieve, it is considered that above it, there would be another sieve with the hole size of ($\sqrt{2} \cdot l_5$).

3. RESULTS AND DISCUSSIONS

The material fractions, separated and sorted in the plansifter compartments, like any granular material, consists of particles whose sizes are between a minimum and a maximum value, the size distribution in the mixture being characterized by different distribution laws.

It is worth mentioning that the material particles, being extracted from different parts of the seed (from the outside to the inside), display different mechanical characteristics and various compositions. These characteristics together with the different size of the particles make each particle act differently in the grinding process. Therefore, the study and determination of the particle-size distribution of every fraction obtained from each frame package in the six plansifter compartments should not be ignored. The hole sizes of the sieve used in the experiments (m_i, mm) and the weight of the material fractions (p_i, %) on each sieve (individually and cumulatively) for the separate material are presented in Table 2.

Every fraction obtained at a set of frames of a plansifter compartment contains and smaller particles than the fabric openings of the package frames. This shows that the separation of the small particles is incomplete, even if the package has a large number of frames. From Table 2, it is observed that particles of the fraction C1-Break 2 have an average size of about 2.27 mm, larger than the fabric openings of the first package of compartment (1.05 mm). We understand, from here, that the particle of the fraction is composed of seed parts of large size (called meals) which must be returned at grinding machine (roller mill) of technological passage Break 2.

Second frames package of plansifter compartment C1, analyzed, is provided with fabric no. 40 (apertures of 470 μm). Particles of fraction C1-Div1', obtained in this frame package have the average size of ~0.58 mm, slightly larger than the size of the apertures. And at this package is particles smaller than the apertures of the frame fabric which has not been sifted (approximately 8.4%), because it did not meet the conditions for separation. This phenomenon is observed in all packages of the plansifter compartment of the mill diagram presented in Figure 1 (as can be observed from Table 2).

Particles sifted at the second package, with frames having fabric no. 40 (apertures 0.47 mm), feeds the third package of compartment C1, which is a package with flour frame. This flour (C1F) has particles of average size 0.08 mm.

At the last frames package of plansifter compartment C1 (no. 56, with apertures size 0.31 mm) are obtained two fractions: a sifting and a refusal. Refusal of this package (C1-Div1"), together with fraction C1-Div1' and with fractions C2-Div1 (of the compartment C2 - see Figure 1) are together pneumatically transported to compartment C5 of breakage phase milling diagram of the milling plant, named Div1.

Fraction C1-Div1" has particles with average size of 0.31 mm (some particles having a larger size, and other below the apertures of package fabric), so that there are particles that did not meet the sieving requirements, even if they are smaller than the apertures.

From direct observations on fractions collected from the plansifter compartments of breakage phase of the milling plant and analyzed in the laboratory of our faculty has noted that fractions of the latest packages of compartment have particles with a high content of shell. At sifting, material on the sieve frames is layered and these particles are placed on the frame in the upper layer which is recommended for they do not come into contact with fabric and sift through the apertures even if some have sizes smaller than the aperture. Staying in upper layers they reach in frames refusal and will constitute either directly into bran or are routed to the finishers to extract endosperm adherent to the shell foils. If these particles get to separate through the apertures, together with particles of endosperm (with dimensions close to this), they will separate anyway pneumatic at semolina machines. From analyzes performed by us, we noted, also, that the particles of flour fractions in all plansifter compartments (of breakage phase) are sized under 0.18 mm and fractions particles refused at the last package of the 5 compartments of phase have sizes larger than 0.37 mm (see Table 2).

Analyzing the correlation coefficients R^2 and χ^2 of Rosin-Rammler function used in the regression analysis of experimental data, for cumulative sifting of classifier used in size analysis, can see that they correspond to a high degree of correlation which shows good properly of function with experimental results. Values of coefficients b and n of Rosin-Rammler function were obtained directly from the regression analysis on the computer. It was found that the correlation coefficient R^2 had values above 0.926 for all analyzed fractions obtained from the plansifter compartments of breakage phase of the milling plant.

Analyzing data from Table 2, but also from direct observations we noted the existence of fractions in which most of the particles have sizes close to the value of the lower sieve apertures of classifier, as well as fractions having most of the particles with average size closer to above sieve of classifier as can be seen from allure of variation curves from Figure 2.

Table 2. Weight values p(%) of the fractions on the shaker sieves and the cumulative weights T(%) of its for grist products collected at entrance and at the outputs of each plansifter compartments C1–C6, and also the mean diameter (d_m) of analyzed grist products

	m (mm)	C1 Entrance p(%)	T(%)	m (mm)	C1 Break 2 P(%)	T(%)	m (mm)	C1 DIV1' p(%)	T(%)	m (mm)	C1 F p(%)	T(%)	m (mm)	C1 DIV1" p(%)	T(%)	m (mm)	C1 M2 p(%)	T(%)
0	0.000	24.20	0.00	0.000	10.20	0.00	0.000	1.10	0.00	0.000	4.20	0.00	0.000	6.00	0.00	0.000	0.60	0.00
1	1.000	8.20	24.20	1.000	21.30	10.20	0.180	2.30	1.10	0.045	45.10	4.20	0.125	8.00	6.00	0.090	1.90	0.60
2	1.400	15.10	32.40	1.400	14.60	31.50	0.250	5.00	3.40	0.063	24.30	49.30	0.180	12.80	14.00	0.125	41.50	2.50
3	2.000	20.20	47.50	2.000	21.60	46.10	0.400	51.70	8.40	0.090	18.80	73.60	0.250	24.50	26.80	0.180	15.00	44.00
4	2.800	27.10	67.70	2.500	20.70	67.70	0.630	28.60	60.10	0.125	6.30	92.40	0.315	32.40	51.30	0.200	30.10	59.00
5	4.000	5.20	94.80	4.000	11.60	88.40	0.710	11.30	88.70	0.160	1.30	98.70	0.400	16.30	83.70	0.250	10.90	89.10
d_m	$d_{1E}=2.13$ mm			$d_{1Break2}=2.27$ mm			$d_{1DIV1'}=0.58$ mm			$d_{1F}=0.08$ mm			$d_{1DIV1"}=0.31$ mm			$d_{1M2}=0.19$ mm		

	m (mm)	C2 Entrance p(%)	T(%)	m (mm)	C2 Break 3 p(%)	T(%)	m (mm)	C2 DIV1' p(%)	T(%)	m (mm)	C2 F p(%)	T(%)	m (mm)	C2 M2 p(%)	T(%)	m (mm)	C2 DIV1" p(%)	T(%)
0	0.000	34.40	0.00	0.000	23.50	0.00	0.000	5.60	0.00	0.000	19.10	0.00	0,000	17.70	0.00	0.000	0.30	0.00
1	0.710	11.50	34.40	1.000	30.10	23.50	0.180	4.00	5.60	0.045	34.90	19.10	0,090	9.40	17.70	0.125	1.60	0.30
2	1.000	22.20	45.90	1.400	13.50	53.60	0.250	7.70	9.60	0.063	21.60	54.00	0,125	22.30	27.10	0.180	5.60	1.90
3	1.400	11.60	68.10	2.000	17.60	67.10	0.400	26.10	17.30	0.090	16.10	75.60	0,180	9.60	49.40	0.250	19.20	7.50
4	2.000	15.00	79.70	2.500	12.40	84.70	0.500	49.20	43.70	0.125	6.70	91.70	0,200	25.10	59.00	0.315	44.50	26.70
5	2.800	5.30	94.70	3.150	2.90	97.10	0.710	7.40	92.60	0.160	1.60	98.40	0,250	15.90	84.10	0.400	28.80	71.20
d_m	$d_{2E}=1.22$ mm			$d_{2Break3}=1.56$ mm			$d_{2DIV1'}=0.52$ mm			$d_{2F}=0.07$ mm			$d_{2M2}=0.17$ mm			$d_{2DIV1"}=0.37$ mm		

	m (mm)	C3 Entrance p(%)	T(%)	m (mm)	C3 FT1 p(%)	T(%)	m (mm)	C3 Break 4 p(%)	T(%)	m (mm)	C3 F p(%)	T(%)	m (mm)	C3 M4 p(%)	T(%)	m (mm)	C3 M2 p(%)	T(%)
0	0.000	31.10	0.00	0.000	3.90	0.00	0.000	5.00	0.00	0.000	0.30	0.00	0.000	1.00	0.00	0.000	0.00	0.00
1	0.500	17.10	31.10	0.710	8.20	3.90	0.250	7.30	5.00	0.045	26.70	0.30	0.090	1.60	1.00	0.090	0.20	0.00
2	0.710	29.50	48.20	1.000	37.60	12.10	0.315	13.70	12.30	0.063	34.00	27.00	0.125	3.70	2.60	0.125	15.00	0.20
3	1.000	1.,20	77.70	1.400	18.40	49.70	0.500	27.00	26.00	0.090	28.10	61.00	0.180	19.20	6.30	0.180	24.30	15.20
4	1.400	3.10	91.90	2.000	27.80	68.10	0.710	39.00	53.00	0.125	10.40	89.10	0.250	71.20	25.50	0.200	51.10	39.50
5	2.000	5.00	95.00	2.800	4.10	95.90	1.000	8.00	92.00	0.160	0.50	99.50	0.400	3.30	96.70	0.250	9.40	90.60
d_m	$d_{3E}=.78$ mm			$d_{3FT1}=1.65$ mm			$d_{3Break4}=0.68$ mm			$d_{3F}=0.09$ mm			$d_{3M4}=0.30$ mm			$d_{3M2}=0.21$ mm		

	m (mm)	C4 Entrance p%)	T(%)	m (mm)	C4 FT2 p(%)	T(%)	m (mm)	C4 Break 5 p(%)	T(%)	m (mm)	C4 F p(%)	T(%)	m (mm)	C4 M4 p(%)	T(%)	m (mm)	C4 M5 p(%)	T(%)
0	0.000	23.80	0.00	0.000	2.70	0.00	0.000	3.40	0.00	0.000	0.10	0.00	0.000	0.90	0.00	0.000	0.40	0.00
1	0.710	22.70	23.80	1.000	12.40	2.70	0.250	5.10	3.40	0.045	0.70	0.10	0.063	6.50	0.90	0.125	1.70	0.40
2	1.000	29.30	46.50	1.400	28.70	15.10	0.315	20.50	8.50	0.063	3.50	0.80	0.090	16.20	7.40	0.180	29.40	2.10
3	1.400	8.90	75.80	2.000	41.50	43.80	0.500	30.40	29.00	0.090	12.80	4.30	0.125	40.20	23.60	0.250	48.10	31.50
4	2.000	13.50	84.70	2.500	11.20	85.30	0.710	34.20	59.40	0.125	30.50	17.10	0.160	16.10	63.80	0.315	18.10	79.60
5	2.800	1.80	98.20	3.150	3.50	96.50	1.000	6.40	93.60	0.160	2.40	47.60	0.200	20.10	79.90	0.400	2.30	97.70
d_m	$d_{4E}=1.17$ mm			$d_{4FT2}=2.03$ mm			$d_{4Break5}=0.66$ mm			$d_{4F}=0.13$ mm			$d_{4M4}=0.16$ mm			$d_{4M5}=0.28$ mm		

	m (mm)	C5 Entrance p(%)	T(%)	m (mm)	C5 MG1 p(%)	T(%)	m (mm)	C5 F p(%)	T(%)	m (mm)	C5 MG2 p(%)	T(%)	m (mm)	C5 M2 p(%)	T(%)
0	0.000	5.90	0.00	0.000	0.30	0.00	0.000	3.60	0.00	0.000	0.40	0.00	0.000	6.20	0.00
1	0.180	6.10	5.90	0.180	1.20	0.30	0.045	50.40	3.60	0.180	1.60	0.40	0.100	2.60	6.20
2	0.250	26.80	12.00	0.250	7.30	1.50	0.063	22.60	54.00	0.250	16.40	2.00	0.125	16.60	8.80
3	0.400	33.70	38.80	0.400	48.70	8.80	0.090	17.80	76.60	0.315	41.80	18.40	0.180	29.50	25.40
4	0.500	21.20	72.50	0.630	31.20	57.50	0.125	4.80	94.40	0.400	38.50	60.20	0.250	40.70	54.90
5	0.710	6.30	93.70	0.800	11.30	88.70	0.160	0.80	99.20	0.500	1.30	98.70	0.315	4.40	95.60
d_m	$d_{5E}=0.44$ mm			$d_{5MG1}=0.61$ mm			$d_{5F}=0.07$ mm			$d_{5MG2}=0.38$ mm			$d_{5M2}=0.23$ mm		

	m (mm)	C6 Entrance p(%)	T(%)	m (mm)	C6 FT3 p(%)	T(%)	m (mm)	C6 F' p(%)	T%)	m (mm)	C6 F' p(%)	T(%)	m (mm)	C6 M6 p(%)	T(%)	m (mm)	C6 M5 p(%)	T(%)
0	0.000	6.60	0.00	0.000	2.10	0.00	0.000	0.00	0.00	0.000	1.00	0.00	0.000	0.10	0.00	0.000	11.10	0.00
1	0.250	3.90	6.60	0.315	13.80	2.10	0.045	0.20	0.00	0.045	12.40	1.00	0.125	0.40	0.10	0.100	15.40	11.10
2	0.315	22.40	10.50	0.500	21.40	15.90	0.063	0.80	0.20	0.063	22.70	13.40	0.180	6.10	0.50	0.125	31.90	26.50
3	0.500	29.40	32.90	0.630	27.70	37.30	0.090	2.80	1.00	0.090	14.10	36.10	0.250	49.10	6.60	0.180	31.30	58.40
4	0.710	32.40	62.30	0.710	27.30	65.00	0.125	24.80	3.80	0.125	42.40	50.20	0.315	38.90	55.70	0.250	9.60	89.70

5	1.000	5.30	94.70	1.000	7.70	92.30	0.160	71.40	28.60	0.160	7.40	92.60	0.400	5.40	94.60	0.315	0.70	99.30
	$d_{6E} = 0.63$ mm			$d_{6FT3} = 0.69$ mm			$d_{6F} = 0.18$ mm			$d_{6F''} = 0.11$ mm			$d_{6M6} = 0.32$ mm			$d_{6M5} = 0.17$ mm		
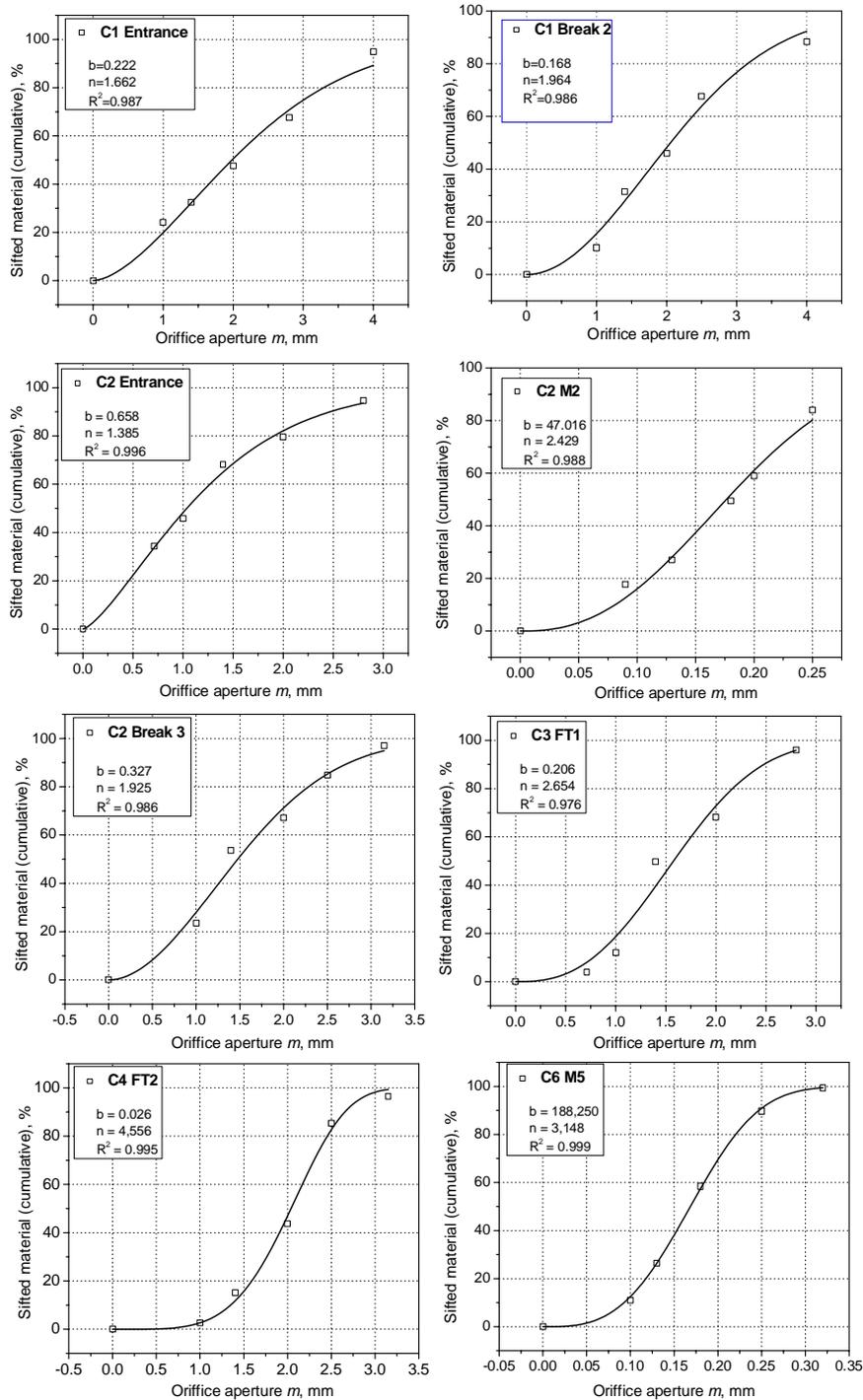
Fig. 2. Cumulative size distribution of wheat grist entering and exiting the six plansifter compartments of a 4.2 t/h mill, data fit to Rosin-Rammler prediction equation $T(m) = 100 \cdot (1-\exp(-b \cdot m^n))$; where: m is mesh size of shaker sieves; b and n – experimental coefficients, [12].

Most fractions size analyzed shows, however, variation curve with inflection point in the middle of the curve (on a Gauss curve they would have a maximum in the middle, without asymmetry). This proves that sieves used for size analysis were chosen correctly (classifier is provided with a set of 30 sieves, and sieves chosen for size analysis were follow the recommendations of experts for such analyzes).

From the analysis of b and n coefficient values in the Rosin-Rammler relationship (equation 1) it can be observed that the 'b' coefficient values are for most of the fractions analyzed under 600. Sifted material with "b" coefficients exceeding 2×10^3 are typical for fractions with small particle sizes (flour or dust), which characterize the dimensional properties of the particles in that fraction.

The values of the n exponent show the degree of uniformity of the particles in the fractions analyzed.

Table 3. The values of b and n coefficients and R^2 correlation coefficient for the Rosin-Rammler sieve distribution law, for grist, at inputs and outputs of the six compartments

Plansifter compartment		b	n	R²	χ²	Plansifter compartment		b	n	R²	χ²
C1	C1 Entrance	0.22	1.66	0.988	17.04	C4	C4 Entrance	0.62	1.96	0.988	21.91
	C1 Break 2	0.17	1.96	0.987	18.89		C4 F	2060.0	5.67	0.997	1.14
	C1 DIV1"	37.81	3.41	0.993	9.15		C4 M4	1150.0	3.97	0.976	36.41
	C1 DIV1'	15.78	6.03	0.997	6.25		C4 FT2	0.03	4.56	0.996	9.07
	C1 F	2200.0	3.05	0.938	142.83		C4 Break 5	2.59	2.98	0.999	1.09
	C1 M2	2860.0	5.03	0.988	20.44		C4 M5	1600.0	6.05	0.999	3.37
C2	C2 Entrance	0.66	1.39	0.996	5.70	C5	C5 Entrance	11.52	3.31	0.993	12.16
	C2 DIV1"	327.36	6.09	0.999	0.43		C5 F	$3.93 \cdot 10^3$	3.23	0.927	176.40
	C2 DIV1'	10.49	4.20	0.988	18.59		C5 MG1	6.17	4.37	0.999	2.07
	C2 Break3	0.33	1.93	0.987	22.80		C5 MG2	545.28	6.96	0.999	0.63
	C2 M2	47.02	2.43	0.989	12.84		C5 M2	171.93	3.78	0.989	18.06
	C2 F	402.15	2.34	0.964	70.89						
C3	C3 Entrance	1.38	1.94	0.995	9.31	C6	C6 Entrance	2.62	2.75	0.999	2.05
	C3 M4	345.27	5.08	0.999	1.02		C6 M5	188.25	3.15	0.999	1.16
	C3 Break 4	2.18	2.85	0.994	9.56		C6 FT3	6.03	5.30	0.989	19.01
	C3 FT1	0.21	2.65	0.976	45.75		C6 M6	$5.5 \cdot 10^4$	9.77	0.996	7.15
	C3 F	2240.0	3.26	0.978	53.40		C6 F'	$5.6 \cdot 10^7$	10.33	0.999	0.22
	C3 M2	$1.07 \cdot 10^5$	7.69	0.997	5.64		C6 F"	337.73	2.86	0.948	82.36

The analysis of the n exponent values for the fractions of each plansifter compartment (Table 3) reveals that they have a wide range of values, but close values for the same type of grist product (for example flour – F), which shows the uniformity of particles both for a certain fraction and between fractions. As it can be seen in Table 3 for C1F – C3F, C5F, n have values in the range 2.3–3.3; an exception is C4F where n = 5.7. Much more variability in n is seen in C6F' and C6F" where n = 10.3 and 2.9 respectively.

4. CONCLUSIONS

For the six plansifter compartments of a milling plant of 4.2 t/h capacity, during the wheat breakage phase, it is important to be aware of the mean sizes of the separated fraction particles, their size distribution and physical composition because they return to the grinding process, and the constructive characteristics of the grinding roll flutes, as well as the functional parameters of the rolls must be correlated accordingly.

The Rosin-Rammler distribution law used in the paper shows a very good correlation with the experimental data on the sizes of fraction particles in all the six plansifter compartments during the wheat breakage phase. The data on the mean sizes and size distribution, on the other physical characteristics of grist fraction particles are also requirements for choosing the appropriate sieving frame braids in the plansifter compartments, from entry into the compartment to the exit of each material fraction.

From the particle size distribution charts, can be determined the mesh size of sieves by which is separated a certain percentage of material. Thus may be established the mesh size for each group of sieves if it aims the

separation of a certain percentage, in accordance with technological requirements. Our charts can be used for that purpose.

At the milling plant analyzed, in the break stages, the mean diameter of the flour particles was under 0.180 mm, which corresponds to all data from the specialized literature. The mean diameter of the semolina particles (separated at the C5 compartment) are between 0.390-0.610 mm, these values also is corresponding with the data from the specialized literature.

The flowsheet of analyzed milling plant show that a high percentage of endosperm particles (semolina) are obtained to the first and second break and so the flour yield of the entire milling plant depends on these two stages. In the break stage C3-C5 the grist products have a high bran content, which are processed in the bran finishers.

The data presented in the paper can be valuable to all the specialists and workers in the field of wheat milling.

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